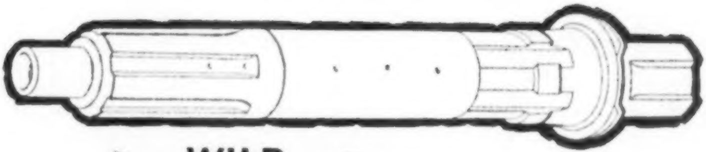
metal treatment

Vol. 26 : No 164 MAY, 1959 Price 2/6



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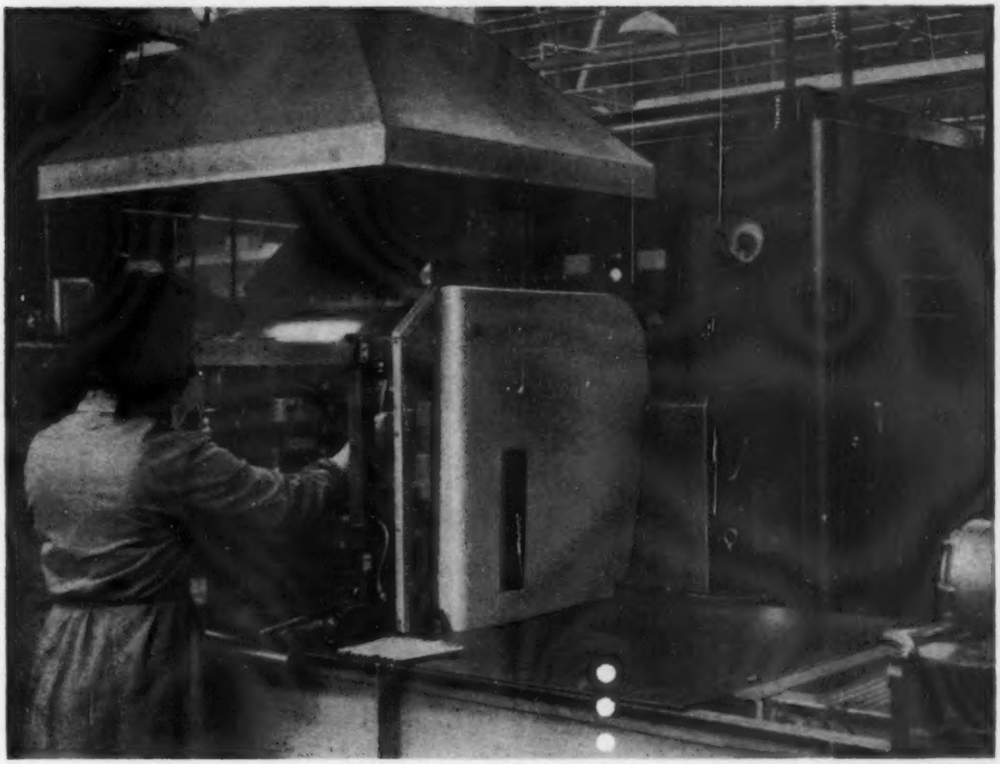


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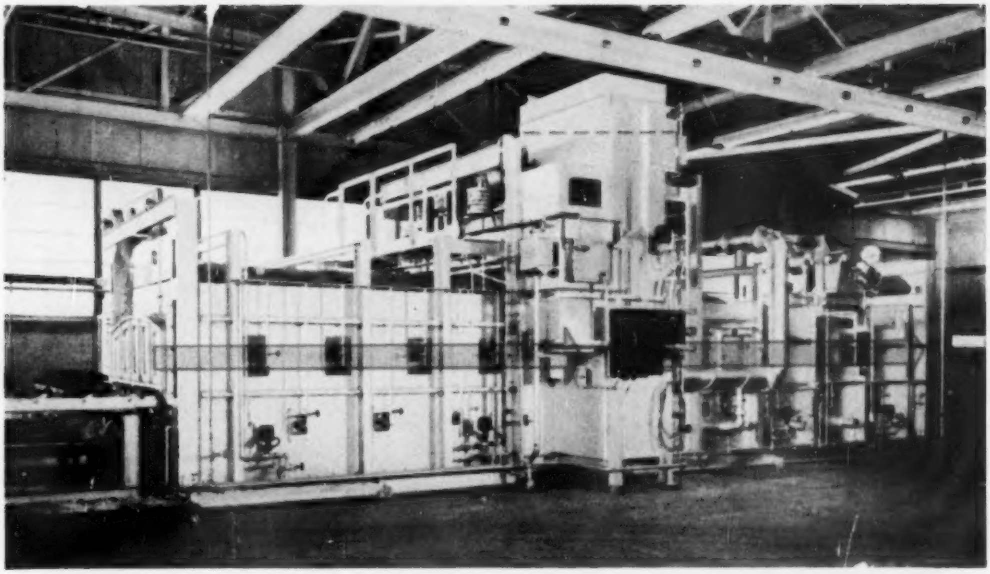

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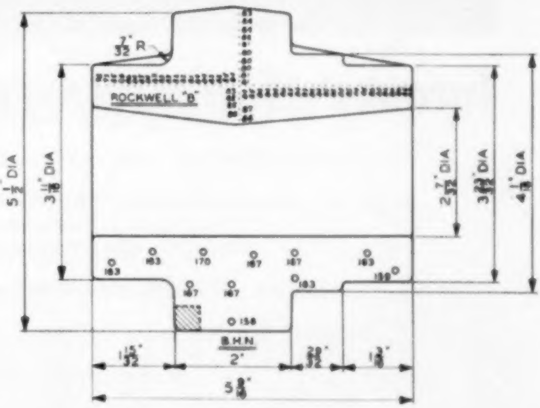

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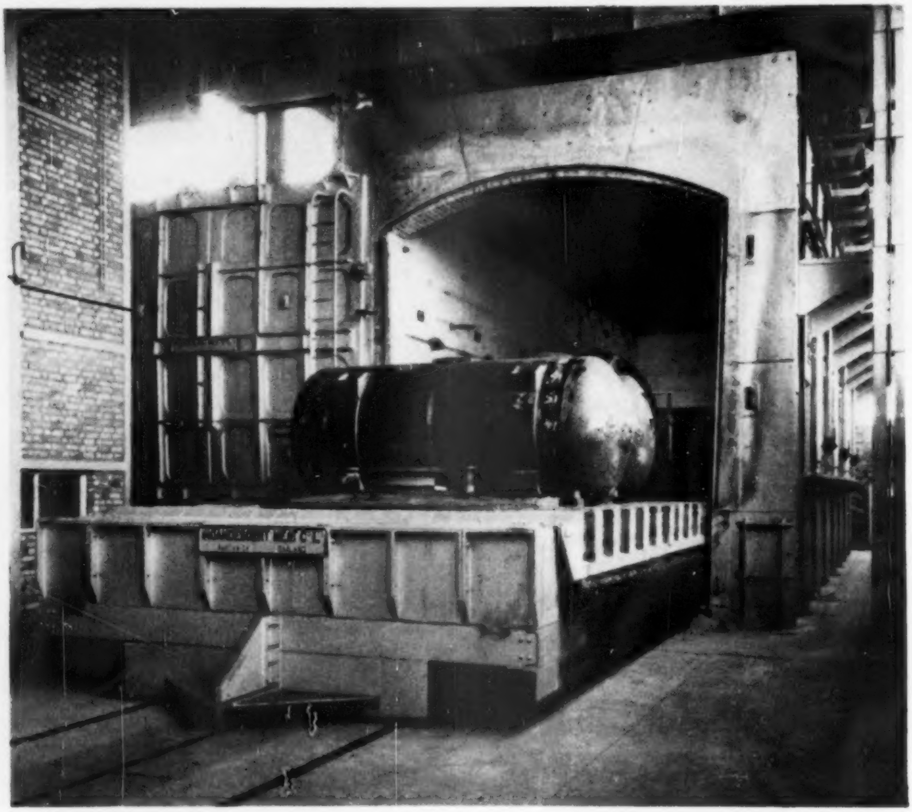

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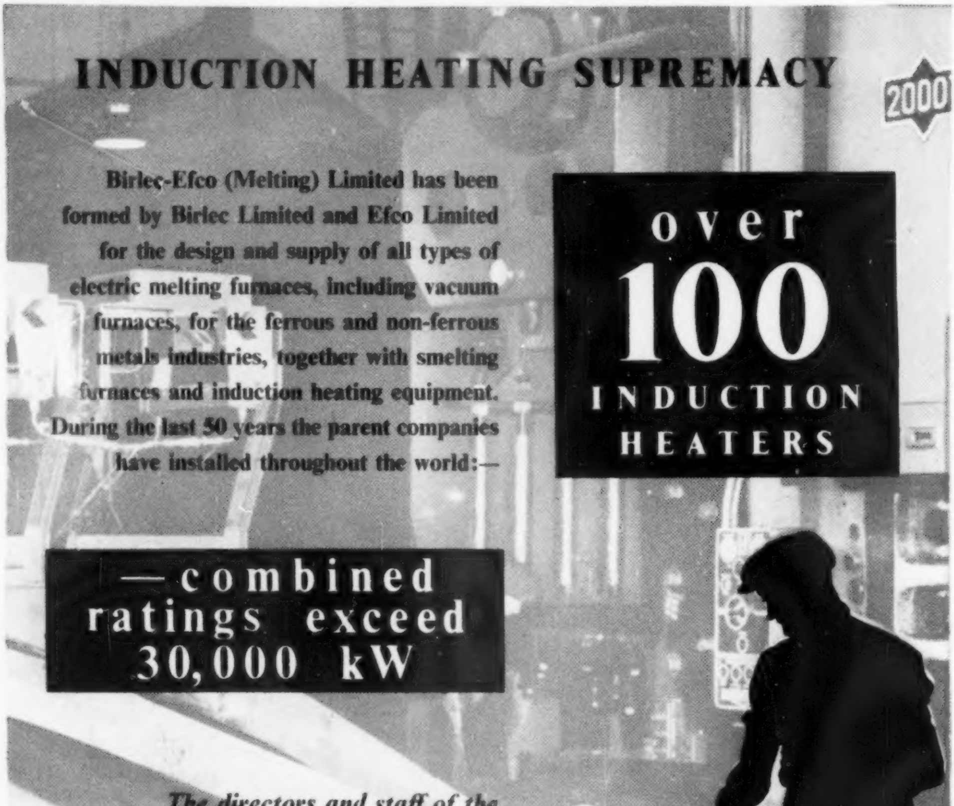
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metal treatment

and Drop Forging

May 1959

Vol 26, No 164

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CONTENTS

This journal is devoted to metals—ferrous and non-ferrous—their manufacture, properties, heat treatment, manipulation, testing and protection, with research work and development in all these fields

One point of view

THE arrival of Spring manifests itself in a number of different ways. To the city-dweller, perhaps the pleasantest is the blossoming of ornamental shrubs, lilac and laburnum in suburban gardens, ornamental cherry and almond along suburban streets, and the appearance of row upon row of tulips in the parks. To the technical journalist, another sign of Spring is the large number of trade and industrial exhibitions to which he is invited. This year's crop has been unusually heavy, to do each one full justice would be almost impossible; instead we propose in forthcoming issues of METAL TREATMENT to discuss some of the most interesting items shown at various places.

An international trade fair which is held in the first weeks of May every year, and where a large number of metallurgical exhibits are normally shown, is the Liège International Fair, Belgium. Shortly before it was due to open this year we were disturbed to receive a press notice from the United Kingdom representative, Mr. R. C. Liebman, headed 'British Industry Shuns the Common Market.' We do not in any way commit ourselves to sharing Mr. Liebman's point of view, nevertheless we feel that his remarks should not go altogether unnoticed, for he says that . . .

'The first thing that hits you in the eye when looking at the list of British exhibitors for the 11th LIEGE INTERNATIONAL FAIR, is how very much smaller the British contingent is in comparison with last year. From nearly 50 firms in 1958, all of which were attracted by the promise of the impending establishment of a European Free Trade Area, only 27 are left, because these hopes failed to materialize, and the most common excuse heard is that "We would rather wait and see how the European Common Market develops."

'What a foolish argument this is, for the longer we sit on the fence the more difficult, indeed impossible, the whole situation is bound to become for any future British participation in the European market. Granted that British goods this year for the first time will be among those having to pay the full duty whilst those of the six member countries of "Little Europe" have lowered theirs by 10% among themselves; this should surely be all the more reason for Britain to remind the world of her existence, particularly in view of the fact that 10% is not so wide a margin as to preclude any chance of a sale. When your competitors are forming a price ring and trying to steal your customers by introducing cut price rates, is that the moment to choose for pulling down the shutters and ceasing to display your goods altogether?

'The recent Treasury report, published only a week before the Budget, that spoke in such glowing terms of our boom in overseas orders had nevertheless to concede towards the end that our exports were already down by £151 million, and likely to drop further at the end of the year. All our success in the United States and Canada will not be sufficient to offset a gradual but complete withdrawal from " Little Europe "—which is not so little as all that, representing as it does no less than 169 million people.

'Although British machinery is still quite well represented it is sad to note the total absence of all manufacturers of industrial safety equipment, despite the fact that they did so well in Liège last year. Nor does it speak well for British enterprise to find not a single British firm exhibiting its products in the three special sections for Plastics in Industry, Industrial Chemistry, and Water Engineering. All the space reserved for British firms there has been fully taken up by French and German firms.'

We do not expect Mr. Liebman's point of view to be shared widely by representatives of British industry. Nevertheless, in the prevailing atmosphere of euphoria and self-congratulation resulting from the strength of the pound it does no harm to be reminded that the picture has its darker sides.

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The purpose of this film was much the same as that made at Consett, to illustrate the life and work of the men who make steel, in this case at the town of Stocksbridge, near Sheffield, where the well-known works of Samuel Fox & Co. Ltd. is by far the largest employer of labour; in fact the town and the steelworks are for all practical purposes one and the same thing. By its quiet restraint and essential good taste, ' Steel Town ' made its impact and conveyed its essential message far more effectively than did ' Men of Consett.' After seeing the two films we could not help being reminded of the old story about the young priest who was given the privilege of reading the bishop's sermon before it was delivered. He noticed here and there the cryptic sign in the margin 'AWSLH.' He asked His Lordship what it meant. 'Ah, my boy,' said the bishop, ' that's most important, it means Argument Weak, Shout Like Hell! '

Application of electron microscopy

Phase analysis of resistance-welded joints in carbon steels

D. and I. HRIVNÁK

This is the third of a short series of articles by different authors illustrating the aid of the electron microscope when applied to specific metallurgical investigations. The present work, covering a study of the phase analysis of resistance-welded joints in unalloyed and low-alloy carbon steels, has been translated from the original version which appeared in 'Hutnické Listy,' 1958, *XIII, No.* 3

RESISTANCE WELDING is characterized by the strong kinetics of the process. Welding of the metal takes place within a period of a few cycles of normal alternating current, with a great, and sometimes even an enormous, current discharge. By reason of its rapidity this method of welding is extremely economical and efficient. The short period of time and the high thermal gradient values create special conditions governing crystallization and phase transformations in the solid state. The heating rate may be partially characterized by the welding times, which on modern hydraulic resistance welding machines vary between 5 and 50 cycles (= 1/50 sec.). During the actual welding operation a growth in the compression force takes place, and so the structure of the welded materials is influenced not only by thermal shocks, but also by strong dynamic factors. Under such conditions it is possible to identify in the structure of the welded joints various transitional and incomplete transformations, the internal structure of which has hitherto been unknown.

The present work covers a study of the nature of phase analysis of resistance welded joints in unalloyed and low-alloy carbon steels and partly a study of carbon diffusion in 16 Cr-13 Ni austenitic steel. In particular, for the great majority of the material on which work has been done there are no characteristic parameters in accordance with which individual joints should be welded. Small changes in the parameters, moreover, do not have a fundamental influence on the structural composition.

This work forms only an introductory study of the phenomena and leads to a profound study of eutectoid reactions which will be presented by the authors in the near future.

The basic structure of unalloyed carbon steels may be ferrite and pearlite, pearlite, or pearlite and cementite. On welding these steels their structure undergoes transformation changes as a result of the influence of heat. While the thermodynamics of the transformation on cooling have at last received partial consideration, the thermodynamics of the intensive and rapid heating have received little attention, and even less has been given to both cycles of the thermal effect.

Since the heating is extremely intensive, austenitization takes place with a very abrupt change in the concentration, and it frequently occurs that the $\alpha \rightarrow \gamma$ transformation involves only a part of a crystal. Since in the α-phase the carbon concentration varies considerably (0·04% in ferrite and 6·67% in cementite) and carbon up to 1·7% is additionally soluble in austenite, austenitization must to a very great extent be accompanied by considerable carbon diffusion. And even though during heating the increasing temperature promotes this diffusion, the short period of the thermal effect is insufficient for complete equalization of the carbon concentration to occur. In the fusion zone its proportions are more favourable to diffusion, and here greater equalization of the concentration likewise occurs.

Transformation in the solid phase may, according to Bowles and Barrett, be divided into two types. One, *i.e.* the martensitic type, does not give rise to internal changes in the orientation of two neighbouring atoms, since the total movement of each atom relative to its neighbour is less than the atomic radius. Many observations show that the activation energy for the formation of the lattice during this transformation is only insignificantly

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compensated by the activation energy for diffusion at the same temperature. The martensitic transformation does not occur at a constant temperature and, when cooling ceases, it comes to a standstill. That the absence of diffusion is characteristic of this transformation is confirmed by the fact that, while this particular phase has a superlattice, the martensitic phase also has a superlattice.

In the other type, nucleation and the creation of a new phase take place as a result of the thermally activated diffusion of atoms from the existing phase to the new phase. This type of transformation is different from the former, namely in that nucleation and the formation of the new phase occur isothermally. As far as the structural state after resistance welding is concerned, both the martensitic and the pearlitic are characteristic.

The pearlitic transformation gives rise to very great carbon diffusion, since the concentration of carbon in the eutectoid solution is considerably different. If a steel contains certain alloying elements (Cr, Mo, Ni), a longer time is required for diffusion, since their diffusion coefficients are of the order of 10^3 to 10^4 times less than the diffusion coefficient of carbon.

Preparation of specimens

In all instances a rapid metallographic method was used. After grinding to grain size 6/0 (Schröder) the specimens were electrolytically polished in a solution of the type $HClO_4$ + CH_3COOH + H_2O or CrO_3 + H_2O + CH_3COOH at normal current densities. In order to reveal the structure, 2% HNO_3 in ethyl alcohol was used, and only in the case of specimens of duplex steel use was made of electrolytic etching in 10% H_2CrO_4 with positive polarity and a current of 6 V.

For electron microscope examination various methods of preparing the specimens were used. Most frequently negative collodion replicas were used, which were shadowed *in vacuo* with up to 1 mg. Cr at an angle of 12—20 deg. In some instances polystyrene single-stage prints were used. A print was obtained at 80—150°C., by moderate pressure of the surface under examination against the polystyrene layer, placed on a glass underlay. The specimen was separated from the polystyrene at reduced temperatures (5—10°C.). *In vacuo* a thin layer of chromium was vaporized on to the print at an angle of 12—20 deg., and the shadowed carbon surface was vaporized at right-angles. Then the polystyrene was dissolved in benzene, and the replicas obtained were washed in several baths.

The carbon extraction replicas were obtained by Smith and Nutting's method. On to the polished, etched and cleaned surface a thin layer of carbon was vaporized *in vacuo* at a moderate angle, and this was done on a vertical stand with a distance of 15—20 cm. between the surface of the specimen and spectrographically pure carbon electrodes. Good results were obtained at a current of 24 V. and an intensity of 40—50 A. The time of vaporization varied between 4 and 8 sec. The carbon film was separated from the surface in 10% HNO_3, then washed in 10% HCl, and in a number of water baths.

For the X-ray investigations cobalt radiation was used with a wavelength of 1·785287 Å units. Silver was used as a reference line. For high measurements the reverse reflection method was used. Micro-hardness measurements were effected by Hanneman's method at a 50-g. load on a Zeiss-Neophot microscope.

Low-carbon steels (0·15% C)

A number of welds in soft, unalloyed steels with a carbon content of 0·12—0·2%, obtained on a resistance welding machine, were subjected to electron microscope examination. It is obvious that the strength of a joint is considerably influenced by its integrity, as well as by its structural state. This work does not deal with the strength of the weld, but only analyses the phase changes which occur during the welding process.

The basic material for all the specimens was ferrito-pearlitic with a structure oriented in the direction of rolling. The heat-affected zone is first of all marked by the pearlitic retransformation from the A_1—A_3 range of temperatures. During the rapid heating austenitization of the pearlitic grains occurred and carbon from these areas was diffused into the surrounding ferrite. Such carbon diffusion occurs primarily on the grain boundaries and along other clearly defined lines where the maximum number of vacant sites exist. From these regions the carbon diffusion also spreads to the ferritic grains which are progressively transformed into austenite. During the rapid cooling which follows the short heating period, the diffusion process is variable, and the $\gamma \rightarrow \alpha$ retransformation is not completed, so that the structure does not revert to its state before welding.

For subsequent comparison, in fig. 1 is shown the different orientation of the pearlitic grains of the base metal area, which are not affected by the heat. Here it is a question of lamellar pearlite, the lamellae of which are distinguishable even at magnifications of ×500—750. On the other hand, fig. 2 characterizes the zone of pearlite retransformation, where, as a result of the short thermal shock, selective infiltration occurs on the boundaries of the pearlite and ferrite. The fundamental pearlitic nucleus preserves its coarse lamellar structure, while the areas which have undergone the $\alpha \rightarrow \gamma \rightarrow \alpha$ transformation have a different orientation, which is

characterized under an optical microscope as ' soft, disintegration phases.' This is a carbon-saturated α-phase, in which the carbide is distributed in very fine lamellar form, very much smaller than that of the original carbide texture.

The micro-hardness of this phase, which qualitatively does not differ from the eutectoid pearlitic transformation, is somewhat less (200—300 HV) than the optical micro-hardness of the lamellar pearlite (300—400 HV).

The zone of the retransformed pearlite is shown in fig. 3, in which it may be seen that there is not only carbon diffusion on the boundaries of the ferritic grains, but also an extremely fine lamellar form of the pearlite. Since it is a question of an extraction print, in the illustration indicated a picture is given of the form of the Fe_3C carbides as originally distributed.

In the further zone affected by temperatures above the A_3 point full austenitization of the material takes place. And, even though conditions were favourable to carbon diffusion, complete equalization of the carbon concentration occurred only in the region of high austenitization temperatures. During cooling a eutectoid pearlitic transformation only rarely occurs, and for the most part in such areas soft and hard disintegration phases are formed with Widmanstätten orientations. In these disintegration phases it is a question of saturated ferrite, in which finely dispersed lamellar carbide particles are distributed in definite preferential directions.

Fig. 4 gives a characteristic and striking example of the Widmanstätten orientation of a disintegration phase with carbides precipitated in step-like layers. It is interesting that a superstructure is formed in the shape of a network of carbides on the freely precipitated ferritic grains (fig. 5). It is probably a question of carbon diffused into the step-like layers, where the carbide phase is formed on cooling. The possibility cannot, however, be excluded that it is a question of tertiary cementite, precipitated at temperatures below the A_1 point.

By optical microscope examination it is possible to discern in the zone affected by temperatures above the A_3 point, firstly refinement of the grain, but in addition some partial coarsening, as transition of the structure occurs towards that of the metal fusion zone.

From the optical microscope it seems as though it were a question of partial arcing of the weld as a result of oxidization of the abutting surfaces. It is indeed true that during resistance welding oxidization of the abutting surfaces does occur, but this oxidization could not be the cause of such extensive arcing. There are two reasons against this: (*a*) it is a question of an extremely short process, during which oxidization could be the cause of arcing of only a small area of the fused metal, and (*b*) oxidization is removed from the weld by, for instance, planing. From electron microscope examination it is possible to explain this apparent arcing as a qualitative transformation in the structure of the precipitated carbide, which at these points is precipitated in extremely fine lamellar form, which causes less diffusion of optical light. Fig. 6 characterizes the fusion zone with such very finely laminated textures of the disintegration phase.

Measurement of the micro-hardness did not show any marked variations and, apart from a gradual increase in the transition zone, which had no material influence on the mechanical and physical properties of the weld, the hardness pattern was not marked by any anomalies.

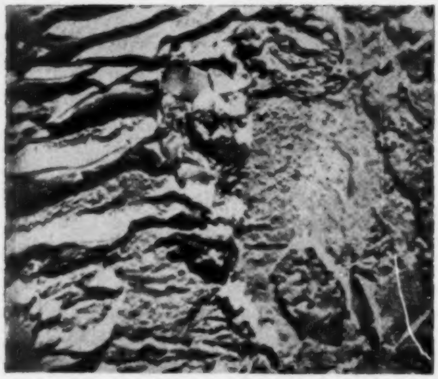
It is often difficult to determine whether a resistance welded joint is the result of fusion or diffusion. From this point of view characteristic signs of fusion joints were observed. On the basis of several experiments it became clear that a good criterion for distinguishing the existence of fusion in a joint in plastically deformed materials is an Oberhoffer macro-etching. This reagent discloses segregation and reveals the ridge-like structure of the material. The ridge-like structure of the material can only be removed by fusion. Thus, for instance, a good indication of a fusion joint is the disappearance of the ridge-like structure in the weld-metal area. In diffusion joints it is only possible to observe deformation of the ridge-like structure in the direction of flow of the metal.

Another characteristic sign of a fusion joint is the manner in which the crystallization occurs around the oxide compounds in the area of the joint. It is known that inclusions and oxides form crystalline nuclei, around which ferrite is precipitated. Where the grains of the material (ferrite) are distributed regardless of the line of the oxides in the area of the weld, it is a question of a fusion weld. But where this disposition strictly limits the grains on one side or the other, then it may also be a diffusion joint.

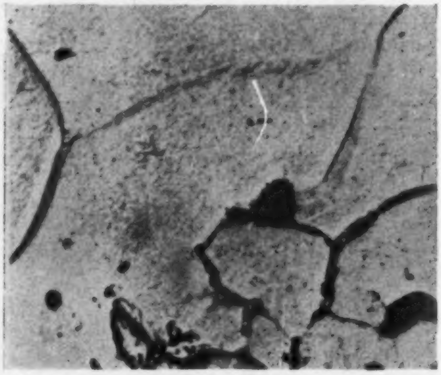
The pattern of the micro-hardness is not a good criterion for the determination of the existence of fusion in a joint, since it only gives a picture of the structural transformations, regardless of their primary crystallization. Although there is some sort of difference between fusion and diffusion joints, and it is also small, it is still within the ranges of the distinguishable values, obtained by measurement.

From X-ray micro-analyses it was clear that the lattice parameter over the whole area of the joint and the heat-affected zone is essentially unchanged, and only a gradual drop in the intensity of the blackening of the Debye lines in the direction of

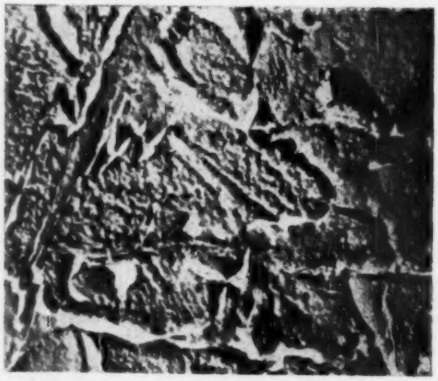
1 *Detail of a pearlitic crystal* × 7,500
Polystyrene-carbon-chromium replica, 2% HNO_3



2 *Zone of retransformed pearlite*
Collodion-Cr, 2% HNO_3 × 7,500



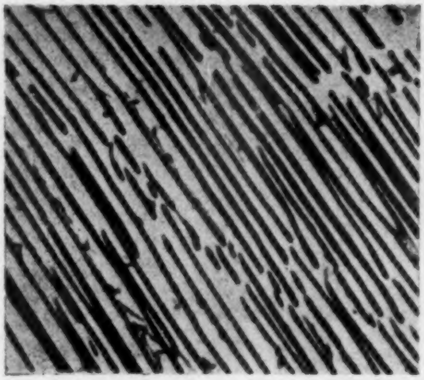
3 *Zone of retransformed pearlite*
Carbon extraction replica, 2% HNO_3 × 7,500



4 *Widmanstätten structure*
Collodion, 2% HNO_3 × 7,500

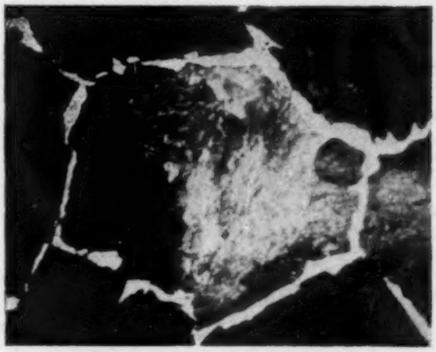
5 *Ferrite with a superstructure*
Collodion, 2% HNO_3 × 7,500

6 *The metal fusion zone*
Collodion, 2% HNO_3 × 7,500



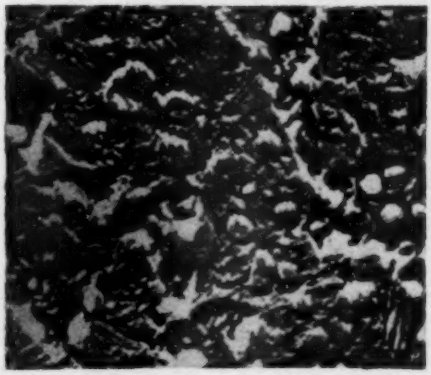
7 *Pearlite*
Carbon extraction replica, 2% HNO_3 × 15,000

8 *Ferrite-pearlite martensite boundary*
Collodion, 2% HNO_3 × 7,500



9 *Zone affected by a transformation without diffusion*
2% HNO_3 × 350

10 *Coagulated carbides with a crystalline sub-structure*
Collodion, 2% HNO_3 × 15,000



11 *The heat-affected zone*
Collodion, 2% HNO_3 × 7,500

12 *A hard disintegration phase*
Collodion, 2% HNO_3 × 7,500

the weld indicated this zone. This drop may be caused by tertiary formations.

Unalloyed medium carbon steels (**0·6% C**)

It is clear that during very rapid welding (more rapid than the cooling) austenite cannot be transformed into the disintegration phases of a soft texture with carbide inclusions, but in the grains martensitic transformations can occur without diffusion. A localized zone of a material, which happens to be in the austenitic range (*e.g.* a nucleus of a pearlitic crystal), can during rapid cooling lead to the thermal hardening of this area in the surrounding ferrito-pearlitic region. This instance occurs relatively frequently in resistance welded joints. For materials with a high content of carbon, the pearlite content will also be higher, and the disintegration phase will be harder. But there will also be a greater risk of local thermal hardening, as well as of thermal hardening of a zone heated to the austenitic range. A good example of such a joint is a resistance weld in unalloyed carbon steel with a content of 0·6% C. The base metal is pearlitic with a narrow ferritic fringe on the boundaries of the grains. The configuration of the pearlitic nucleus, unaffected by heat, is shown in fig. 7.

The material examined was relatively coarse-grained, and the eutectoid temperature, which separates the austenitic and ferritic zones during welding, had affected half the pearlitic grain. As a result of the rapid cooling this zone was transformed without diffusion with a high degree of hardness (up to 1,100 HV_M). Fig. 8 is an electronographic print of the boundary between the untransformed pearlite and ferrite and the product of transformation without diffusion, which has preserved its original orientation. But nearer to the weld in this structure the carbides start to precipitate into lamellar formations.

Up to the present time the mechanism of martensitic transformation has not been unequivocably described, neither under conditions of rapid cooling, nor under those of rapid heating, which, combined with high pressures during the welding process, may lead to divergence from the process as observed in the laboratory. It is also illuminating that three phases can exist side by side with different properties—soft ferrite, which even in martensitic surroundings, forms the boundary of the former α-grains (fig. 9*); pearlite, which as a result of the shortness of the thermal shock and the low sub-eutectoid temperature did not undergo transformation ; and the product of retransformation without diffusion which has no martensitic contours.

**This photograph is from the same material, and it was kindly provided by P. Slysko.*

This phenomenon can only be attributed to the fact that the thermal shock caused an isothermal temperature effect, since the eutectoid temperature (721°C.) did not affect even half of the pearlitic grain. It must be pointed out that this was not a static or quasi-static effect, but a dynamic thermal shock, which to such an extent localized the transformation zone that on the boundary of the unaffected pearlite there is no gradual transition in the concentration. The existence of a localized area of the original ferrite in a zone of transformation without diffusion may be explained by the fact that, at the low temperature and during the short time for carbon diffusion, austenitization could not take place at these points.

This joint, of which the mechanical properties are completely unsatisfactory, is at the other extreme of the whole scale of structures which occur in resistance welded joints in unalloyed carbon steels. Joints which have satisfactory mechanical properties have structural orientations similar to those described in the foregoing section.

High carbon content steels
(**1·19% C, 1·24% Cr**)

All the ranges of structures which are found in resistance welded joints in unalloyed and low-alloy carbon steels are difficult to cover exhaustively in this short treatise. As an interesting example of phase analysis, a resistance welded joint in high carbon content steel with austenitic material of the type 16 Cr-13 Ni will be discussed. The basic material was ferritic with spheroidal carbide formations, the structural nature of which it was impossible to distinguish with the optical microscope even at the highest magnifications. From electronographic analysis it became clear that it was a matter of plate-like (peltate) formations which at sub-eutectoid temperatures are transformed into spheroidal formations (fig. 10).

The investigation of the sub-structure of these carbides is extremely interesting. From the structure of the sub-lattice, as from many other experiments also, it becomes apparent that in no instance is it a matter of an artefact which could be caused by the technique of producing the prints. One of the authors recently observed the crystalline sub-structure of an intermediary σ-phase in austenitic 16 Cr-13 Ni steel, which was probably developed out of carbides of the type $(Fe, Cr)_{23}C_6$. This other example of the occurrence of a crystalline sub-structure may be evidence of the fact that it is a question of similar phenomena, since the spheroidal particles in fig. 10 are likewise carbides of Cr. The low micro-hardness of the basic structure (~200 HV) refutes every idea that this ferritic structure is saturated by carbon. In the outer heat-affected zone fundamental changes occur

in the configuration and the actual structure of the carbide phase. This is dissolved in the austenitic matrix and, on cooling, has a tendency to form lamellae.

Fig. 11 shows the tendency towards a lamellar structure of the carbides which, however, are distributed as extremely finely dispersed particles in the saturated ferritic matrix. The spheroidal formations of the chromium carbides are difficult to dissolve and retain their crystalline structure. Nearer to the weld greater homogenization of the austenite occurred and, on cooling, the carbides are precipitated from the ferritic phase in a fine form. Here, however, it is also possible to distinguish the original areas of carbides which still do not have a sub-structure. The whole orientation of the carbides reminds one of the Widmanstätten structure, which is extremely close to the martensitic structure (fig. 12).

In the first series of experimental welded joints the welding technology was not sufficiently developed to obtain satisfactory mechanical and structural values for the joints. In all instances there occurred in the transition zone a hard martensitic structure without striation, or with fine striation. Fig. 13 characterizes this structure with fine martensitic striation, in which is visible the beginning of the precipitation of the carbide structures. The micro-hardness of this structure attains 1,100 HV_M in the case of diffusion joints and 600 HV_M in the case of joints with a fusion character. The lower hardness of the martensitic phase, where other conditions remained equal, may be explained by carbon diffusion into the austenite (such diffusion was revealed), which was comprehensibly greater in the fusion joints than in the diffusion joints. And a decided part may also be played in this by the accumulated energy of the latent heat of solidification, which could moderate the intensive cooling.

In order to determine the character and extent of the carbon diffusion into the austenite, for each of the diffusion joints heating was carried out for 150 h. at a temperature of 650°C. with subsequent cooling in the furnace to 300°C. and thereafter in air. In the product resulting from this heat treatment there was carbon diffusion from the carbides to the ferritic matrix, where there was formation of coarse-grained areas with an optically visible sorbitic character. The grain boundaries were fringed with a carbide substance, the hardness of which could not be determined owing to its small dimensions. It was, however, greater than the hardness of the sorbitic disintegration phase. Electronographic examination, however, revealed lamellar structures in the disintegration phase with very fine pearlitic structures.

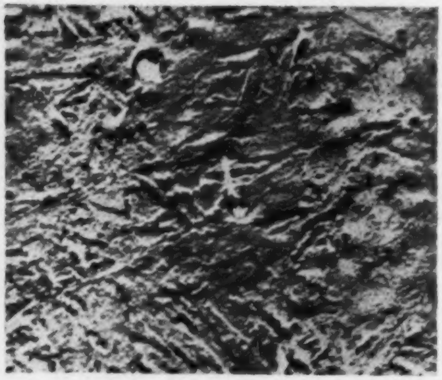
The carbide substance surrounding the sorbitic grains again had a crystalline sub-structure, from which it is possible to judge its identity with the carbide structure of the preceding analysis. It is interesting to study the morphology and structure of this crystalline sub-structure, which has, so it appears, a fairly regular hexagonal structure (fig. 14). In all instances, indeed, this was observed at a given distance from the boundary with the neighbouring phase. But not only is the structure of the pearlitic (sorbitic) grains heterogeneous, but in the structure it is also possible to discern various anomalies to which it is difficult to give interpretations.

Thus, for instance, fig. 15 shows dual crystallization of cementite lamellae with 'coarse' and very fine structures. Most interesting of all is the revelation that between the coarse lamellae it is possible to discern the crystallization of finely laminated foliates. After prolonged heating an extremely fine pearlitic (sorbitic) substance was formed out of the original martensitic zone, and this substance had lamellae which were much less oriented in the basic direction (60°). In the transition zone this resulted in intensive carbon diffusion into the austenite. This decarburization resulted in the formation of free ferrite alongside the carbon steel. It is possible that it is a matter of chrome ferrite, for it is not possible to suppose that there is diffusion of chromium into the austenite; rather on the contrary (fig. 16).

Interesting also is the electronographic study of the boundary between the carbon and austenitic steels. As a result of the carbon diffusion it is impossible to establish without ambiguity that the boundary in fig. 17 is austenitic; rather it may be a localized ferritic area with extremely finely precipitated carbides. In this 'neutral area' the carbon diffusion is brought about only on the boundaries of the γ-grains and in other directions where there is intense precipitation of carbide particles without distinct regular orientation. The morphology of this probably already austenitic area is characterized by fig. 18. In the further diffusion area precipitation of chromium carbides occurred on the boundaries of the γ-grains with its characteristic crystalline sub-structure (fig. 19).

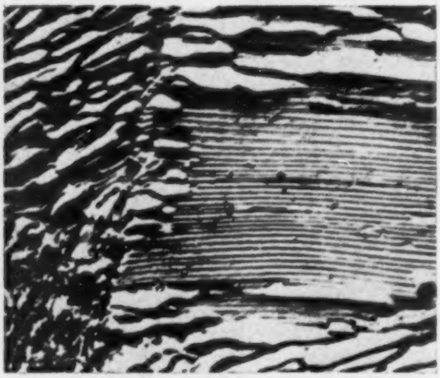
Discussion

In optical metallography it is customary to make qualitative discrimination between the products of eutectoid transformations according to their appearance at definite optical magnifications. Thus, for instance, the lamellar structure of pearlite is initiated by the growth of carbides with lamellar structures, between which are lamellae of ferrite. Troostite is formed during rapid cooling in the eutectoid temperature range, and optically has no lamellar structure. In addition to this difference,



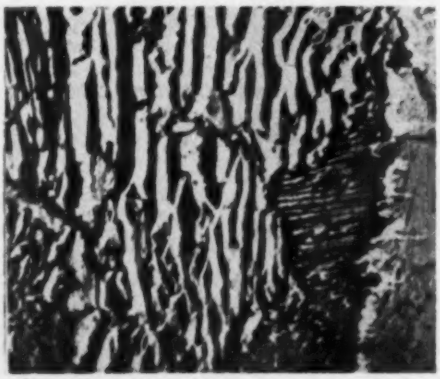
13 *Martensite with fine striation*
Collodion, 2% HNO_3 $\times$ 7,500

14 *Orientation of the sub-structure of the chromium carbides. Collodion, 2% HNO_3* $\times$ 7,500

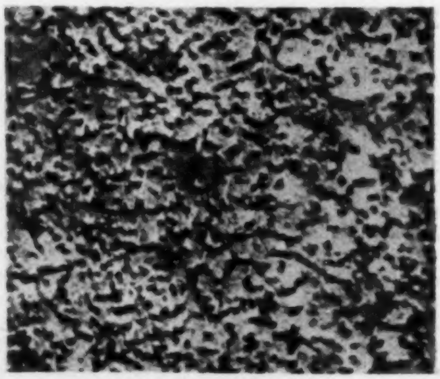


15 *Anomaly in the structure of the pearlitic grain*
Collodion, 2% HNO_3 $\times$ 7,500

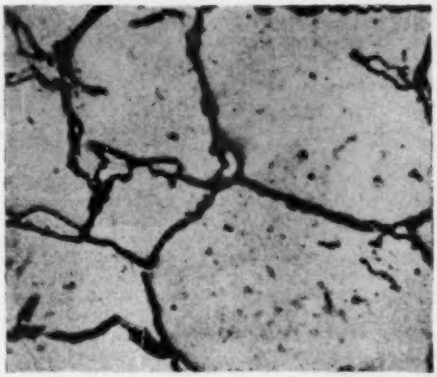
16 *Ferrite in the transition zone*
Collodion, 2% HNO_3 $\times$ 7,500



17 *Transition zone*
Collodion, 10% H_2CrO_4, 6 V. $\times$ 7,500



18 *Another area of carbon diffusion*
Collodion, 10% H_2CrO_4, 6 V. $\times$ 7,500



19 *Carbon diffusion on the grain boundaries Collodion, 10% H_2CrO_4, 6 V.* × 7,500

there also occur differences in their physical and mechanical properties, such as strength, density, macro- and micro-hardness. These differences are so great that by them it is possible to define the various structural components. At the large magnifications obtained electronographically, however, it is possible to determine that it is a matter of lamellae, the only difference between which is the coarseness of the lamellae and the distance between them.

Thus, for instance, the structure shown in figs. 1 and 2 is pearlite, but the structure shown in figs. 14 or 15 is also pearlite. The only difference is the ten-fold refinement of the lamellae, which it is understandably impossible to distinguish optically. It is an established fact that the mechanical properties of both formations are different. It must, of course, be remembered that in the study of mechanical properties and their comparison, we are not approaching the problem from the aspect of a comparable structure, but from the aspect of a comparable composition. Thus, in the case of the coarse lamellar pearlite, properties are obtained for a pearlite-ferrite complex, whereas in the disintegration phases it is a question of a more homogeneous composition. Qualitatively the disintegration phase shown in fig. 7, for instance, differs from pearlite. And where it is a matter of a very much smaller lamellar structure, the cementite lamellae are extremely fine and do not have a linear orientation.

A striking indication is given by the discovery that in the disintegration phases with a Widmanstätten character, elementary carbide lamellae are also precipitated at an angle of 60 deg. or even 120 deg. And these linear lamellae lie within the limits of 0·1—0·15 micron. The whole structure has the appearance of saturated ferrite, because even though its carbide lamellae are extremely fine (less than 0·01 micron), the inter-lamellar spacings are many times greater (up to 10 times).

The structure of the pearlitic grains is also extremely complicated, and the anomalous phenomenon of the dual transformation, evidenced by fig. 15, may also be explained by the fact that by the precipitation of the chromium carbides the area surrounding them is enriched in this component. During cooling there took place a pearlitic transformation, initiated by the iron carbides, Fe_3C, and the ferrite, enriched with chromium, filled the inter-lamellar spacings. With the further reduction in temperature there is formation of complex carbides $(Fe, Cr)_2C$, which are precipitated in a sub-lamellar form with a comparable orientation.

Likewise the crystalline sub-structure of the chromium carbides, as shown in fig. 10 or 14, is singular, and likewise its regular lattice structure. As has been mentioned, this sub-structure was observed during the formation of the σ-phase in austenitic steel (16 Cr-13 Ni). In order to reveal this, on that occasion electrolytic etching in 10% NaOH at 6 V. was used, but in this instance the existence of the sub-structure was revealed by a 2% alcohol solution of HNO_3, and in some cases electrolytically in 10% H_2CrO_4 at 6 V. Since it was a question of three different reagents, there can be no doubts about the fact that the crystalline substructure forms part of the internal structure.

In some instances it is possible to observe a regular hexagonal structure of the crystalline elements. Therefore two explanations are possible: (*a*) Either the crystalline sub-structure is peculiar to a certain type or types of chromium carbide, or (*b*) the crystalline structure is characteristic of a certain internal orientation, a certain crystallographic composition without regard to the elements which crystallize in it. But it is not excluded that it is a question of both possibilities. The revelation of a crystalline sub-structure in the carbides portrayed in fig. 19 strongly supports the first alternative. Among the physical properties of this phase only its hardness, which was appreciably higher than 400 HV_M, was discovered.

Conclusions

In the present work, phase analysis was carried out on joints obtained by resistance welding in various groups of steels. Joints in unalloyed, low-carbon material with a content of 0·12—0·15% C, a resistance welded joint in medium-carbon steel (0·6% C) with a thermally hardened zone, and duplex resistance welded joints in high-carbon, austenitic material, were chosen as typical.

It was discovered that various transition and disintegration structures are distinguishable with an electron microscope by the manner of precipita-

tion, and the form, of the precipitated carbides. Even in the case of a product of a transformation without diffusion, all the carbide formations are lamellar and qualitatively (in essence) indistinguishable. And the softest disintegration phase is ferrito-cementitic by reason of its orientation and structure, and by reason of the lamellar carbides. In these latter phases, however, there is a qualified relationship between the coarse lamellar formations and the interlaminar ferritic filler. While in pearlite this proportion is 1: 6, in the latter instance the relationship is 1: 10 in favour of ferrite. The discovery is also important that, whereas the complete structure has a Widmanstätten character, yet the basic carbide lamellae form a serrated line with an angle between the teeth of 60 deg. or 120 deg. This applies likewise to the case of isolated precipitation from the saturated ferrite.

In the case of resistance welds in steel with 1·19% C and 1·24% Cr an interpretation was given of electronographs of the phase composition of high-carbon, low-alloy steels.

The authors draw attention to the crystalline sub-structure of the chromium carbides of the type $(Cr, Fe)_2C$. The transitional carbides which arise during the diffusion of carbon into the austenite are morphologically interesting.

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NEW FILMS

'Drop Forgers in Steel'

THE LATEST technical film of English Steel Forge and Engineering Corporation Ltd., Sheffield, is a continuation of the E.S.C. Group policy of covering the individual activities of its subsidiary companies as follow-ups to the first E.S.C. general film, entitled ' Engineers in Steel,' which was made a few years ago. It was selected for showing at the ' Festival of Films in the Service of Industry,' in Harrogate last month, and is the second E.S.C. film to be honoured in this way, the first being ' Forgemasters in Steel ' in 1958.

' Drop Forgers in Steel ' begins with a general introduction to the plant used in the drop forging industry, and describes the metallurgical properties which the drop forging process gives to a component, explaining, amongst other properties, the importance of grain flow. A 4-throw crankshaft for a commercial vehicle is shown at all stages of manufacture, beginning with the machining of the die blocks and making of the steel and ending with finish-machining and inspection. Another feature is the whole sequence of forging a large 6-throw crankshaft for a diesel engine. The final sections of the film deal with the large variety of E.S.C. drop forged components manufactured for the automobile, petroleum and aircraft industries; these sequences include many scenes taken ' on location ' at the works of users of E.S.C. drop forgings.

' Drop Forgers in Steel ' is a 16 mm. colour film and takes 35 minutes to show. Produced by the E.S.C. Film Unit under the guidance of the E.S.C. Film Committee, it was completed in under a year. It will soon be put on general release to educational and industrial organizations, and applications for free loan should be made to the Publicity Manager, English Steel Corporation Ltd., River Don Works, Sheffield, 9.

British Iron and Steel Federation

Two new films produced for the British Iron and Steel Federation by Merton Park Studios, are mainly intended for use in foreman training. It is clearly important that foremen should understand the financial structure of their companies so that they fully appreciate management policies and decisions in financial matters. Equally they should know the system on which departmental production costs are calculated since the co-operation of foremen in this field is vital to efficiency.

The ground covered by the films and the presentation is such that they are quite suitable for showing to other audiences at all levels in a company. They may also be of interest outside the iron and steel industry, since the principles they explain are of general application.

' *Money and Steel* ' illustrates the capital structure of a typical company. For the purposes of the film an imaginary integrated steelworks of one million tons capacity is taken as an example to explain how the capital of a company is tied up in fixed and current assets. Animated diagrams are used to show how the company's income pays for raw materials, wages and salaries, services and other expenses, and how the final trading surplus is allocated to taxation, dividends and reserves. The way in which fresh capital and reserves are utilized to pay for development and expansion is also explained. Runs for 9½ minutes, 16 mm. or 35 mm.

' *Counting the Cost* ' This film explains how delays in production caused by breakdowns, mishaps or carelessness affect production costs and therefore profitability. In the cost accountant's office we see a chart showing how daily production fluctuates against the target line of standard working. Selecting some of the black spots when production fell steeply we see how these were caused. A cobble in the mill or an electrical failure in a crane start a chain of events that bring production to a standstill and we see what this means in terms of idle time, loss of yield and extra heating costs, quite apart from the basic fall in output and cost of repairs. Runs for 10½ minutes, 16 mm. or 35 mm.

The forging industry

Past, present and future

G. H. JACKSON, F.I.M.

This article, which is concluded in this issue, is based on the first lecture in the series ' The forging of steel,' currently running at the Wolverhampton and Staffordshire College of Technology. The author, who is Technical Officer of the NADFS, has traced the development of forging hammers and open and closed-die forging techniques, and now goes on to discuss other methods of forming such as press forging, upsetting and light-alloy forging. He concludes by considering some recent developments in forming methods and of furnace design in the light of future requirements

Press forging

THE AMERICANS are accredited to be the first to use a forging press which is, of course, much more modern in its conception than hammer equipment already described. The use of forging-press technique has received a very great stimulus from the close-tolerance requirements of the motor-car industry.

Unlike drop forging, press forging is not so versatile in the shapes that can be handled, principally because, under a press, the form has to be developed in one stroke as against several under a hammer. Thus the more simple symmetrical forgings such as gear blanks, crown wheels, etc., lend themselves readily to press production. Although it has been said that forming is in one stroke, three separate stages are usually involved, namely scale breaking, forming a simple cheese and moulding.

A further aspect of importance which has contributed to an increasing interest in the press is that it requires less skill to operate than a hammer. It has previously been pointed out that, despite the closed die for hammer forging, considerable skill is still required in carrying out fullering and blocking before the final form is struck. Despite the father and son tradition still to be found in the industry, the skill of the hammer-man is a dying art, a fading away that has coincided with a big increase in the demand for automobile parts. The forging press at least partly meets this deficiency. Despite this attraction in favour of the press, relatively few are to be found in operation, due to their extremely high initial costs compared with hammers of the same capacity.

We must clearly differentiate between the press of the forgemaster, the heavy presses as used in the light-alloy forging industry, and the forging press. The two former applications are invariably slow, ponderous hydraulic-type presses, whereas the forging press is a fast-stroking mechanical press.

Forging presses are of two main designs, namely the eccentric press and the crank press. Press forging requires much greater forces than is required of hammers, the normal range being 600—3,000 tons capacity. Thus they are inherently of heavy, robust construction.

In the case of the eccentric press, there are many features considered to be important improvements over the crank press. Eccentrics with integral gears allow for increased diameters and rigid masses, thus avoiding the bending and twisting associated with crankshafts. Furthermore, in the case of the eccentric, the mandrel is static as distinct from the rotating shaft of a crank press. Hence the bearing problems of the eccentric press present far less difficulty. Very much more safety against mis-use is claimed for the eccentric press because of its massive rigidity. The result of an error in a top dead-centre dimension of a crank press is only too well known by many unfortunate setters!

Reducer rolls

As already stated, press forging does not lend itself to such operations as fullering and swaging down stock. To overcome this difficulty, reducer rolls were devised as ancillary equipment to the press. Reducer rolls or forging rolls consist of a pair of driven rollers with suitable grooving to

ensure substantial reduction of stock at each pass. The rolls are incomplete, some 15% of the circumference being lost because of the necessity for flats to form a gap so that the stock can be inserted and removed.

The early reducer rolls were designed as an integral part of the press, being built into the side of the press and operated by the press mechanism. This proved an inefficient idea, the use of the rolls being seriously limited by such factors as press operating speeds. Apart from this aspect, they were only utilised for 50% of the time, when it was obvious that one reducer roll could feed two presses. The modern reducer roll is a separate piece of equipment and, in the case of the Wilkins & Mitchell Rollmaster, is actually portable.

The rolls of the modern machine are cantilever mounted, thus reducing bearing problems, but, above all, making for easy and rapid changing of roll sets for different applications. The machine is extremely rigid and capable of reducing stock by as much as 55% at one pass through the rolls.

Thus, by pre-forming with rolls of the type just discussed, the versatility of the forging press is extended well beyond the simple symmetrical production mentioned at the beginning of this subject.

Reducer rolls have been in use for a very long time in the edge-tool industry, particularly in the Sheffield area. They are used extensively for the production of forks and similar tined implements, or, where considerable swaging and drawing down is required as in the case of the tangs on agricultural tools. Their use in this capacity demands considerable skill and is yet another specialist branch of the art of forging.

Upsetting

Upsetting belongs to the category of closed-die press forging. Upsetters are sometimes known as forging machines and can be considered as presses operating in the horizontal position, doing the work by means of a continuous squeeze pressure. A multi-impression progressive split die is used. The heated bar stock, suitably gripped, is longitudinally upset, each portion of the die increasing the upset relative to the bar diameter. Thus, first or second stages can be likened to fullering in a drop die, or the preparation of a ' use ' for final moulding.

An important requirement in a modern upsetter is rigidity, hence the machine frames are very massive. Modern machines are fitted with overload devices to prevent breakage of the moving parts. The size or capacity of an upsetter is given in inches. This is a rating carried over from the days when the machine was used for bolt heading. At that time, the size rating in inches indicated the largest diameter of bolt head that the machine would take. Today, only experience can be used as a guide to top capacity, as can be readily understood when one considers the considerable variation in hot ductility of simple carbon and complex alloy steels.

Light-alloy forging

Mention has already been made of the light-alloy forging industry. Though of much smaller output than the steel-forging industry, it is nevertheless of vital importance to the aircraft industry. Without the progress made in the last two or three decades, development of aircraft and aircraft prime movers would have suffered considerably.

The technique of light-alloy forging differs considerably in many respects from that of steel. To start with, whereas forging temperatures for steel are in the range of 1,100—1,300°C., aluminium and its alloys are forged in the region of 400—450°C. and magnesium even lower. Thus heating problems are simpler yet need much closer control by pyrometric equipment.

Many of the tools of the light-alloy forge are the same as for steel. Hammers are used with closed dies, but the forces necessary are somewhat more than those required for steel. More use is made of crank-type presses and friction-screw presses for small forgings and, unlike steel, use can be made of massive hydraulic presses in conjunction with closed dies for such large forgings as aircraft undercarriage forks. There is at least one such press in constant operation in the country with a 12,000-ton capacity. The largest presses in the world are at the Wyman-Gordon plant in the U.S.A., where one 35,000 and one 50,000-ton press are in production for large aircraft spars and like requirements.

Some of the statistics of the 50,000-ton Loewy press are interesting.[8] It is used for closed-die work and forges aluminium parts up to 500 lb. in weight and 12 ft. in length. Its dead weight is 10,605 tons, the total weight of the moving head being 6,450 tons. It stands 48 ft. above and extends 66 ft. below ground level. The foundation on which the equipment is mounted extends 100 ft. down to bed rock.

The press is hydraulically operated by water pressure delivered at 4,500 lb./sq. in. and pressures of 6,000 lb./sq. in. are reached during operations. A standard die set measures 20 ft. by 10 ft. and the press has a stroke of 6 ft.

It is only necessary to consider these statistics to realize that such ancillary equipment as die sinkers and heating furnace must be *pro rata* in size. The cost of such an installation seems enormous, particularly in relation to its very limited output in numbers of specialized components.

Hot-brass pressing

Having mentioned almost in passing the relatively small but highly important light-alloy drop-forging industry, one must not overlook another extensive process that falls within the general heading of forging and stamping. Hot-brass pressing is also in itself an ancient trade. Though very similar in die requirement and plant requirement, as briefly outlined in drop forging, greater use is made of the press and particularly the friction-screw press than free-falling hammers.

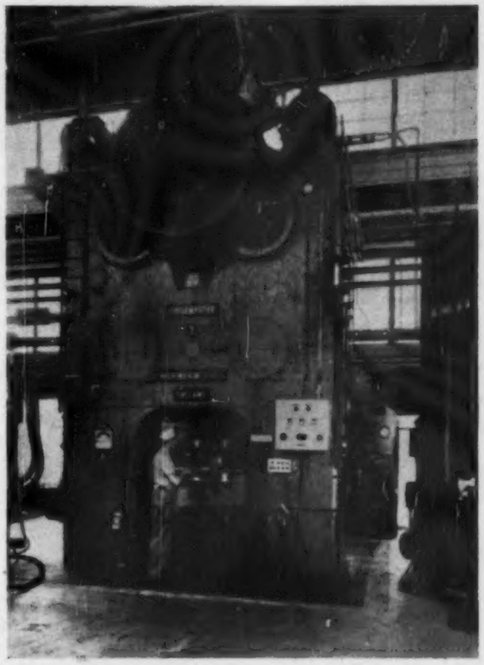
Unlike drop forging in steel, a considerable amount of work has been carried out recently in developing what is referred to as a sub press for coring hot-brass pressings.

The sub press consists of four horizontal tools, usually situated at 90 deg. to each other, although there is no fundamental reason why different subtended angles between the required cores could not be obtained. These tools are made to operate in cycles in conjunction with the press carrying out its normal function of die shaping by vertical displacement.

Such equipment is capable of producing accurately cored tools in such as Tee pressings in brass and light alloy, and there is an indication that it will not be long before the same process can be extended to steel. In fact, it is known that in America such a coring operation is carried out on relatively heavy steel forgings on a 4,000-ton press, which is equipped with two side rams, each of which can be operated at 2,000 tons each. This equipment appears to be unique and in all probability arose as a result of the specific requirements of the oil and petroleum industries' need of large valve parts and similar Tee junctions.

Electrical upsetting

Although not mentioned whilst discussing the fundamental type of horizontal upsetters which developed from the bolt industry, a more modern application is that of electrical upsetting. In the electrical upsetting process a steel bar is heated by



9 *High-speed forging press*

10 *Modern reducer rolls*

Wilkins & Mitchell Ltd.

passing an electric current directly through the bar, applying end-wise pressure simultaneously so that the bar is compressed on to itself, thus upsetting the steel to several times its original diameter.

In some instances, for example the manufacture of internal combustion engine valves, the upsetting is completed by forming the valve head in dies incorporated in the upsetting tools, whereas in other instances the process is used to prepare a ' use,' which is then die formed in the more usual way, usually utilizing a vertical-type friction screw press.

The process is not restricted completely to symmetrical cylindrical objects, but is nevertheless nowhere near as versatile as drop-hammer techniques, or, for that matter, reducer-roll technique, in handling the more asymmetrical types of forging.

So much for a review of equipments and the ancillary needs to the process of forging. It is a story of slow development over the centuries although by far the greatest impetus to all the processes discussed is a direct result of the particular requirements of the automobile and aircraft industries. The needs of these industries has been a steady progress towards even a closer dimensional control of even more intricate shapes in materials subject to higher stresses and design requirements than ever before, and by and large the industry has met the challenge and produced the results.

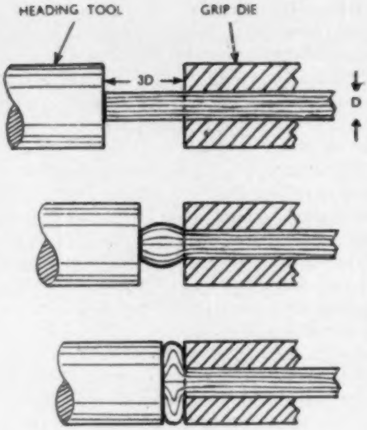
The industry has its problems in its raw materials which are to a great extent beyond its control.

Steel and defects

It has been previously mentioned that hot working, particularly by forging, results in a directional grain flow of the steel, thus giving maximum strength at section changes and other points of the designer's choosing. Natural heterogeneity and banding invariably found in a steel serves a very useful means of pictorially tracing what happens when the metal is subjected to hot plastic deformation. In other words, misfortune in the form of steel defects has been turned to good usage.

In the development of steels, and particularly in the U.S.A., much work has been carried out to produce what they call a ' desegatized ' steel, which is a steel free from segregation of the type mentioned. If this should ever occur in the bulk production of steel used by the forging industry, flow lines will disappear and what will the inspector do then?

During the development of the forging process, the steel industry has developed along its own lines and requirements, only a small part of which is directly appropriate to the forger's requirements. Although there is what is vaguely referred to as a ' forging-quality steel ' and an ' upsetting-quality



11 *Principle of simple upsetting*

steel,' they are not all that could be desired from the point of view of hot processing.

By far the greatest cause of complaint in connection with steel during forging are such defects as seams, laps, subcutaneous blow holes and like defects which burst during working as a result of the multi-directional flow to which metal is subjected. Because of the infinite variations of shapes of forgings and, consequently, the direction of this flow, it is impossible to define just what constitutes a defect and just what can be tolerated. The ideal is complete freedom from these defects known to be objectionable during processing. Although steel making is an extremely fine art, it cannot always guarantee this degree of freedom, so that the main essential of drop forging and upsetting specifications today involves extra work to remove these defects at the ingot and billet stage.

Apart from physical defects in steel, materials involve other problems requiring considerable control. Naturally, the forger uses as high a temperature for forging as possible, as in this condition the material is in its most plastic condition, yet serious damage may arise if the top limit of heating is over-stepped. This results in overheating, abnormal grain growth which is not necessarily broken down by the further hot working, or even burning of the steel, a condition which cannot be salvaged.

One is inclined when thinking of steels to think of the simpler carbon specifications, but, of course, industry demands forgings in the medium and high-alloy steels. As the alloy content of the steel increases, so the hot ductility progressively decreases until, with such materials as stainless steels and high alloys of this nature, the material is

distinctly stubborn to deformation by the forging process. This aspect introduces problems of die strength and die wear and hammer capacities.

The designer, not satisfied with using 'sticky steels,' demands even tougher specifications, particularly for the modern gas-turbine work. To quote but a few there are the Nimonics, high-alloy heat-resisting steels, medium-tungsten steels and last, but by no means least, titanium.

Because of the difficulty of the behaviour of the many materials that flow under impact or steady pressures, very considerable experience in die design is necessary to obviate forging defects such as internal bursting, folds in the hot metal, flash difficulties and, above all, cracking in the partly or fully formed forging.

Die design is not only concerned with these matters but is also closely bound up with the type of equipment on which it is to be used. The designer must have an intimate knowledge and experience of such preforming operations as 'fullering,' edging and blocking, to prepare a shape capable of moving in a final impression to obviate the many defects mentioned.

This information cannot be obtained from a book, most of the knowledge not even being empirical but 'rule of thumb.'

Future requirements

Unlike many other industries and trades, forging interests have been backward in taking advantage of technological development and research. As has already been outlined, forging has grown as an art and, although metallurgy is an essential part of the production process, far too little of the knowledge available today is used either as a means of control or of progress. Indications are, however, that this is now realized as a shortcoming and it can be confidently forecast that the deficiency will be at least partly remedied in the not-too-distant future. Failure to do so may make serious inroads into the output of the industry as the big user industries such as the automobile are constantly supporting new ideas of casting and fabrication.

Entirely apart from the desirability of investigating those factors which can lead to more economic production, there are considerations arising from specialist application in the aircraft industry as a result of the fully established position of the gas turbine. Materials are becoming increasingly complex and, consequently, more expensive as the duty demanded of them increases. The forger must strive to produce to much thinner sections, much closer tolerances and much less draft, thus saving expensive material and, often just as important, expensive machining operations.

How such developments in design requirements resulted in a change of method of initial manufacture can be seen in the case of turbine blading. In the early days of the gas turbine all high-temperature turbine blading was made by the lost wax or investment casting process. Cost and quantity demanded a new technique which was solved by precision forgings. Thus the casting lost out to the forging. History can repeat itself, not only with expensive aircraft parts, but with automobile requirements, unless the industry vigorously presses forward with plans to elucidate some of the fundamentals of their requirements.

There are many aspects of the process requiring scientific investigation. The mechanism of plastic deformation of hot metal under multi-directional flow, the rate of deformation, measurement or definition of forgeability are but three major metallurgical factors. Die life, certain types of die design and die-block requirements are some of the mechanical problems, quite apart from problems of heating for forging by oil, gas, electricity and induction.

Manufacturers of plant for the forging industry are active on design problems. The increasing use of multi-impression dies which results in off-set loading of the tup has necessitated improvement in Vee guides, as wear in these parts leads to mismatch dimensions in the plane of the forging. High rates of production have given impetus to

12 *Modern hot-brass stamping press*

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attention to the requirements of control gear for continuous operation of free drop hammers. The application of such improvements in the industry is slow because of the very high capital outlay in equipment relative to value of the article it is producing.

Mention was made earlier in this paper of the use of reducer rolls. The conception of the method will be enlarged in the future by incorporating the equivalent of closed dies. Bearing in mind that much of die design in simple rectangular blocks is 'rule of thumb' and experience, it will be appreciated that design on a cylindrical surface is not likely to be an easy matter. However, it is capable of solution, but, even then, a new technique in die sinking would have to be developed.

Spark erosion

A recent development likely to pay a very important part in the future of die design is spark erosion. Spark erosion utilizes the force of an electric-spark discharge between an electrode and the workpiece to mechanically dislodge particles of metal. The electrode is of a positive shape of the cavity required in the block or cylinder.

The electrode is fed down into the block as erosion takes place by a suitable servo mechanism, the rate depending upon the power being utilized. More than one electrode is used to complete an impression, and rates of erosion are varied to suit ultimate surface finish required.

Hitherto, most die sinking has been carried out on heat-treated blocks. This eliminates distortion and cracking in subsequent treatments, but it determines the maximum hardness of the die impression in use. It is known from experience that certain shallow impressions permit very hard die faces with a corresponding increase in die life. Spark erosion will perform equally as well in hard materials as soft—in fact, its development was initiated by the requirements of shaping tungsten carbide sintered components. By its application, therefore, it may be possible to investigate the advantages to be derived from such hard die facings as stellite—materials which hitherto could not be worked after deposition by normal means.

Cold extrusion of steel

Perhaps the most startling future development will be seen in the field of cold flow forging or cold extrusion of steel components. Impact extrusion of light alloy and similar non-ferrous alloys in tube manufacture has been developed and exploited for a long time. The extrusion of steel components is a later development and has introduced some complex problems. Though not solved by any means, many of these problems are more fully understood.

Cold extrusion requires pressures of the order of 120 to 180 tons/sq. in. as against 25 to 35 tons/sq. in. in forging. Such requirements reflect on the type of press equipment which necessarily will be expensive. This in turn suggests that the possible application of the process lies in large quantity runs. Apart from equipment cost, long runs are indicated because of the relative ease with which the whole process could be automated by transfer mechanisms.

In the early application of the process, suitable parts had to be symmetrical and usually cylindrical both internally and externally. The indications today, however, are that asymmetrical shapes in split dies are more than a possibility and it is this aspect which may prove a serious competitor to hot forming. The components produced can be held to a high order of accuracy and the method fundamentally ensures considerable improvements in the physical properties of the steel used. Both these aspects are important 'wants' by the engineering industry and must serve as a powerful impetus to research into the method.

As yet, two factors are important to the process. Firstly, lubrication of the blanks to be worked is of vital importance. This is usually by a phosphate coating and considerable research is going into improvements and better understanding of the requirements. Steels, as yet, have not been specifically developed for cold extrusion. In this matter the Continent has already recognized the importance of suitable specifications. America is beginning to issue specifications to meet the needs of the process, but, though it is known that work has been carried out by the steel workers, no special specifications have yet been published in England.

The development of cold extrusion will be a joint effort of machine, lubrication and steel requirements, but is likely to make marked progress in the not-too-distant future.

Other new forming methods

A recent paper was read indicating possible advantages obtainable by an almost simultaneous application of force by impact and hydraulic pressure. This work indicates that there is still much to be investigated in the application of the forces required in hot working, or for that matter, in cold working.

Coining as a means of obtaining close dimensional tolerances has received scant attention in the past and is a subject calling for investigation. It could well offer a means of obtaining the required size control in a cheaper and more efficient way

than imposing further restrictions to the actual forging process.

Various other methods of forming metals are under consideration, particularly in the U.S. A remarkable performance has been obtained by the use of explosives in forming shapes. The U.S. workers have shown that, by the use of high forces and very high rates of deformation obtainable by explosives, materials hitherto difficult or impossible to form can be shaped. To date most of the work has consisted of mounting a flat sheet over a cavity of the required shape and firing explosive on the other side of the sheet, thus 'blowing' it into the cavity.

It has been reported that mild-steel swarf, baled under pressure and then hot forged, will weld to produce a homogeneous mass very similar in properties to the same article produced from the solid bar.

Such examples may be no more than interesting experiments. Their future may be very limited, but, on the other hand, may be forerunners of an efficient and cheap way of forming the requirement at least of certain industries. In any case, it illustrates a move to investigate aspects which the British industry should have had enough foresight to consider on a forward-thinking basis.

Furnace design

The heating of steel for forging needs considerable thought. Without a doubt, the scale produced in heating is deleterious in several ways. It wastes material, it aggravates die wear, it is dirty and makes for poor working conditions and it is dangerous, as it flies off the anvil at each stroke.

Heating for forging tends to be crude and inefficient. There are many reasons as to why these difficulties persist, but, nevertheless, development is being undertaken by furnace makers to improve several aspects of the heating operation. Attention is being paid to resistor-bar types of electric furnaces, this type of element being virtually the only medium of obtaining the high temperatures by radiation heating. As yet they are mechanically weaker than one would really like to see, but it can confidently be expected that many of the difficulties being experienced in experimental furnaces will be overcome by the makers of the resistor rods. A marked improvement in their loss of efficiency has already been achieved in this country, a very big factor when one considers running efficiency.

In the field of gas heating a marked improvement, particularly from the point of view of prevention of scale formation, is the 'Equiverse' system of regeneration. A furnace of this type not only provides a protective atmosphere, but by efficient heat exchangers results in a much higher overall efficiency. Although the furnace may run as high as 1,300°C., flue-gas temperatures in this equipment are as low as 200°C. at the point of emission in the furnace.

As has already been indicated, oil is a preferred fuel and, again, developments are constantly in hand to improve the burners and the air-proportioning devices. There has also been some quite interesting work and results published on the use of high-velocity gas flames, which might ultimately be incorporated in furnaces for heating for forging.

It has not been possible to discuss other aspects of forging production, namely the heat treatment to which forgings are subjected after hot working. Such treatment is, in many cases, very necessary to correct grain growth occurring during heating for forging, which may or may not be satisfactorily broken down by the work applied. Heat treatment is an extremely extensive field; suffice to say that it introduces problems and is the subject of considerable development, but it could not be claimed that any of this was specifically applicable to forgings only.

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Co-operative training in Sheffield forges

At a time when so much is being said about the ' bulge ' and about the lack of co-operative training for small companies and when the need for a new approach to training is so apparent, a scheme operated by a number of smaller companies in the Sheffield area may be of interest.

Industry is faced with the fact that larger numbers of young people will be leaving the schools in the next few years. The larger company can do much to train its own recruits and give to them opportunities of a type which the small company can rarely achieve.

One solution which has been much discussed, but about which little has been done, is that small companies could get together and run their training schemes in co-operation with each other. The Sheffield forging industry must be one of the first in the field. Since September, 1957, eleven companies with forges have been fully participating in a co-operative training scheme. Another has recently joined the scheme. Besides this, other large companies who do their own practical training have been supporting the scheme and making use of the further education classes arranged for the trainees.

Of the twelve companies making full use of the scheme, seven employ less than 600 people, the other five employ between 1,000 and 4,500. The smallest company employs 50 people. The three large companies who support the scheme and make use of it in part all employ over 5,000 people.

The scheme in brief

Companies are responsible for recruiting the boys they want into their own forge departments. Entrants so far have come from secondary modern, technical and grammar schools. The boys are given a minimum agreed starting wage and spend two years in the training scheme before taking a place in a production team. Three days of each week are spent in the boy's own company where he is given instruction and guided observation in the forge and in other departments.

One other day is spent at a separate site where he receives instruction on a hammer with about three boys from the other participating companies. Training is graded so that each boy begins with simple operations with easily worked steels until he gradually progresses to more difficult work. His final training is given on a hammer engaged on production work and with production teams.

The remaining day of the week is spent at the Granville College of Further Education, Sheffield, during term time. Here each trainee takes a course in general education including English, Calculations, Social Studies, Elementary Science and Metalwork and a City and Guilds of London Institute Iron and Steel Operatives' Certificate Course. In the first year this is the General Iron and Steelmaking Certificate. In the second year it is the special Forgings and Stampings Certificate. In addition to all this, visits are made to manufacturers of plant for forges and to other related industries.

The scheme, now in its second year, was planned by managers and training officers from the companies, assisted by members of the British Iron and Steel Federation Training Staff.

Training hammer installed

So successful has the scheme proved that already 24 boys are taking training and the companies agreed in February, 1959, to buy a hammer to be used for the bulk of the communal hammer training. Such a scheme costs money. In its first year three companies gave the use of hammers to the scheme for a nominal hire charge. Now, though two of these hammers will still be used for special training, the third company has agreed to install on its own site the hammer being bought for the scheme.

So that a full-time instructor may be employed to give instruction, to co-ordinate training and to help in completing a Forge Training Manual the companies have also agreed to pay a fixed sum for each year of each boy's training.

The scheme attracts a good type of recruit and gives him as a trainee in a forge production department better chances than he has ever had before. It helps the company, too, by training skilled young operatives to whom it can look to carry on the best traditions of the forges.

As a joint effort of small companies, of large companies and of the British Iron and Steel Federation Training Department the scheme is an example of what can be achieved in co-operative training.

An important feature of the scheme is that it has sprung from the industry's needs and has been supervised by the men who are responsible for the product—the forge managers themselves. Following the success of the scheme other working parties of managers have got together under the auspices of the British Iron and Steel Federation Area Training Committee in Sheffield to consider the needs for training in wire-drawing departments, rolling mills and melting shops.

Lithium

Appreciable quantities of lithium were produced during the Second World War for the first time since its discovery in 1817. The following article, the fourth of a series on the newer metals appearing in this journal, summarizes the discussion of the applications of the metal given in French by Ingénieur-Docteur André Roos in 'La Metallurgie,' September, 1958

LITHIUM, DISCOVERED IN 1817, has only been produced industrially in appreciable quantity during the Second World War. After the end of hostilities the demand fell rapidly and a steep increase in production is now in progress despite prices which are still high. It can be reckoned that in 1952 the American production of lithium carbonate—the raw material for the metal and its derivatives—was 3 million lb., and the estimates for 1958 are over five times that figure.

Ores and production

Former methods of production took the greater part of the basis salts required for production from sea water in the form of impure chlorides. Nowadays, spodumene—a mineral from North Carolina (Kings Mountain district), which is also found in the Black Hills district of South Dakota—is utilized. The Carolina mineral contains as much as 6% lithium oxide and the veins are rich and abundant. At Searles Lake in California there are deposits representing 100,000 tons of lithium chloride (American Potash and Chemical Corporation).

The main difficulty has been to concentrate the lean ores and to separate the rich parts, particularly at Searles Lake. The basis ore assays at only 0·10% oxide. Nevertheless it has been possible to extract up to 10 lb. lithium by the treatment of about 1 ton of ore.

It is only recently that rich lepidolite ores of Kings Mountain have made it possible to extract lithium economically at the Foote, North Carolina, factory through new chemical processes of high efficiency.

Lepidolite is a variety of alkaline mica which, like zinnwaldite, contains lithium and fluorine. The beautiful violet tint which these two micas often give to granite make highly valued ornamental rocks. Neither lepidolite nor zinnwaldite ever occurs in masses of any size, but always in the form of thin plates or spangles (the Greek word *lepides* means 'scale') in granitic rocks of the granulite class.

The average proportion of mica in normal granitic rocks is about 25%, which means that a ton of lithium-bearing granulite contains about 250 kg. (about 560 lb.) of lepidolite. The numerous analyses made on lepidolites have shown that, according to the proportions of fluorine and alkali metals, the lithia content may vary from 2 to 6%, the part generally higher in iron oxide containing only 2 to 3% lithia.

Since the formula of lithia is Li_2O the metal forms 46·66%. Thus 1 ton of well-mineralized granulite with 250 kg. of lepidolite contains about 10 kg. (about 22 lb.) of lithia and 4·66 kg. (about 10·2 lb.) of lithium metal, *i.e.* a metal content of the rock of 0·466%.

At the present time the applications of lithium are divided as follows: (1) Lubricating greases 35%; (2) ceramics and glass 27·8%; (3) metallurgy, 14·7%; (4) accumulators and miscellaneous 10·2%; (5) air conditioning 7·3%; and (6) welding and brazing 5%.

Looking ahead 20 years, the order is foreseen to be as follows: (1) Metallurgy; (2) ceramics and glass; (3) lubricating greases; (4) air conditioning; (5) welding and brazing, and (6) accumulators and miscellaneous.

The alloys of lithium are now in process of becoming the most important source of lithium consumption.

Lithium in metallurgy

Lithium metal has a density of 0·53, being the lightest of the metals, and a melting point of 180°C. Its corrosion resistance is rather poor and it readily forms nitrides when exposed to moist air. It undergoes combustion in air at about 200°C. Its mechanical properties are characterized by great ductility and very high malleability. It is easy to roll, forge and stamp and in general one can subject it to any amount of deformation with great ease. Its pressing characteristics are excellent. It is the low weight of the metal, coupled with its ease of melting and welding, which seems to indicate it

for particular applications. Its mechanical strength can be increased by alloying metals, but researches to this end are still in their early stages.

The greatest difficulty stems from its very poor resistance to corrosion and its small resistance to temperature. Researches in hand at the present time promise to make it possible to find means of preventing corrosion and of endowing this metal with good resistance to heat.

The most encouraging tests have been with alloys with aluminium. One of the drawbacks of aluminium is its readiness to oxidize at high temperatures which brings about the formation of an adherent, hard layer of oxide which prevents welding or at any rate makes it much more difficult. By incorporating lithium with aluminium, oxidation is reduced by a significant degree.

This fact raises great hopes for the industrial application of aluminium-lithium alloys. This would make it possible to overcome all the drawbacks so far encountered in the application of aluminium, particularly for electrical equipment.

Aluminium-lithium alloys

The development by the Aluminium Co. of America of an aluminium-lithium alloy for aircraft should open up new outlets for aluminium and one looks forward to a greater utilization of the light metal in supersonic aircraft. Whereas the conventional alloys of aluminium begin to lose their physical properties between 120 and 170°C., Alcoa claim that a new alloy designated X 2020 keeps its strength at 205°C.

Lithium not only confers resistance to elevated temperature but increases the elastic modulus of the aluminium by 8% and diminishes the density by 3%. The material can be worked to shape by the processes current today in the aircraft industry.

Magnesium-lithium alloys

Magnesium is a metal of low ductility and the same is true of its alloys. This fact seems to derive from the hexagonal structure of the metal, which consequently has very limited capacity for deformation. This low ductility is the source of fabrication difficulties and also reduces the number of possible applications.

It has been found that, with lithium, magnesium makes possible the production of alloys that are malleable and ductile at ordinary temperature. It has been established that starting with 10 to 15% lithium, most of the alloys of magnesium show a cubic structure and that the above-mentioned properties are further improved. These facts are again confirmed for the ternary alloys, for which a further hardening can be obtained, and this enables good strength results to be attained for a given weight of metal.

Nevertheless a certain instability of strength has been observed, especially after age-hardening, even at room temperature. In consequence, ternary additions have been tried with the intention of keeping the strength undiminished. In this way, the hardening effect of cadmium, zinc and aluminium has been established, although these do not confer stability.

Silver, copper, tin and cerium, on the other hand, bring about a smaller but more lasting hardening. A hypothesis has therefore been suggested on the stabilizing effect of these latter metals in the magnesium-lithium alloys containing a metal of the first group, such as zinc, for instance.

Thus, for example, an alloy composed of magnesium 88 and lithium 12 which contains 7·5% zinc or from 9 to 18% cadmium has been modified by the addition of 3% silver. In agreement with the hypothesis, this latter metal has a strong stabilizing effect on the basis alloy. At 16°C., no loss of hardness has been detected even during 100,000 h. (about 12 years). However, at 50°C. the initial hardening is followed by a softening which occurs after only a few hundred hours.

A second hypothesis has been suggested in consequence. Two authors (Jones and Hogg) have sought to find if the change in the ratio, e/a = number of electrons/number of atoms, for the alloy caused by the addition element can improve the stability or if, on the other hand, it could reduce it. To this end a series of tests was made, during the course of which additions of 1 atomic % of antimony or nickel were made to a basis alloy composed of magnesium, lithium and zinc.

A 5% reduction of hardness having been chosen as the criterion of hardness stability, it was verified that antimony, which increases the e/a ratio of the alloy, reduces the stability, as does nickel.

Sodium may have a similar effect. And it would not be surprising that small percentages of this metal which is always present in lithium could be the cause of certain defects in the alloys of lithium and notably in the lack of permanence of the hardness. This effect of sodium has been pointed out by Eynon in particular in connection with alloys containing 13·5% lithium. Results of tests in the as-cast condition, as well as after 24 h. ageing at 200°C., are given in Table I.

TABLE I *Effect of sodium on 13·5% lithium alloy*

Na %	Elongation %	
	As-cast condition	After 24 h. ageing at 200°C.
0·0085	39	0
0·0070	39·5	9
0·0025	44	35
0·0019	39	36·5
0·00025	42	41

For less severe thermal conditions similar results have been obtained. Thus for an alloy containing 12% lithium and 0·017% sodium, the elongation falls from 39% to 6% after six months at room temperature. The same alloy containing only 0·0105% sodium undergoes a drop in its elongation from an initial value of 42% to 34%, 19% and 4% as the result of heat treatment at 100°C. for 1, 8 and 64 h.

If it is established that the production of a high-strength magnesium-lithium alloy requires very low residual amounts of sodium, this could constitute a serious handicap in industrial practice. Nevertheless, it appears that the utilization of highly pure lithium, coupled with the fabrication of a magnesium-lithium-aluminium alloy, possibly containing boron, is one of the reasons behind the success of the American firm Armour which has announced a new alloy.

Despite official secrecy being observed, there is talk in light-metal circles of a new alloy whose composition would be 13% lithium and 6% aluminium, balance magnesium, and it is thought that prototypes incorporating this alloy are already in being. The inherent difficulty of atmospheric corrosion of the lithium alloys would thus seem to be solved, at least as regards this type of application.

As regards heat treatments, numerous processes have been utilized. After hot rolling, hardening treatments at 16 or at 75°C. were at first adopted, but these have been replaced by other methods. After a lengthy treatment at 450°C., followed by ageing at 75°C. for 200 h., maximum hardness was attained. This hardness, however, is accompanied by considerable fragility, especially in the case of the magnesium-lithium-zinc alloys, but less so for the magnesium-lithium-aluminium alloys. For these alloys, as well as for the cadmium-containing alloys, cold rolling modifies the grain structure and brings about the disappearance of the grain-boundary precipitation. Treated in this way the alloys have remained unchanged for more than six months at normal temperature.

Miscellaneous applications

Greases containing lithium compounds are relatively new and date from the last war. It may be estimated that the world consumption of these greases in 1957 was 4,000,000 lb. and it appears that their future utilization will be on the increase. There are very many problems in grease applications where the qualities of lithium may completely replace the grades of lubricant used at present.

Air conditioning Lithium salts act as desiccators in moist air because they behave as a sponge absorbing the humidity. Only the supply difficulties relating to stainless steels have held up the application of lithium salts in industrial air-conditioning apparatus and one must look forward to the increase in the years to come of this process which has given excellent technical results.

Accumulators Nickel-cadmium and nickel-iron accumulators as well as the ultra-light silver-zinc accumulators make use of a basic (alkaline) liquid composed principally of potash.

It has recently been found that the addition of lithia to the potash distinctly improves the efficiency of the electrolyte. This is a very novel application which could prove interesting in the future.

Ceramic industry Enamels based on lithium salts or oxide are characterized by excellent covering or obliterating power and remarkable brilliancy and opacity. Further, these enamels have coefficients of expansion which can be readily varied by certain methods or by changing the lithium oxide content. Also the salts of lithium markedly lower the fusion temperature and the expansion coefficient of the enamel, which greatly facilitates their utilization.

The highly siliceous glasses exhibit an atomic lattice whose structure is particularly influenced by silica. The lithium ion, considered as an agent for structural modification, is not predominant in this case. Any addition of alkaline bases to silica brings about a loosening of the bonds in the crystal structure by reason of the breaking of the silicon-oxygen-silicon linkages at the apices of the tetrahedra centred round the silicon atoms. This is not the case with glasses containing lithium, glucinium (beryllium) or magnesium.

It is known that the presence of lithium brings about the formation of 'condensed' glasses and ceramic materials with densities exceeding those determined by calculation. For minerals, eucryptite has a mineralogical density of 2·362, whereas in the vitreous state its density is 2·429. In the same way, spodumene goes from 2·280 to 2·388.

Mathematical demonstration of the effect of lithium in the formation of denser glasses confirms experimental results obtained for the permeability of glassy silicates to gases. A low permeability to helium has been established for the lithium glasses, whereas the potassium-base glasses are much more permeable.

An interesting practical application of the effect of the contraction due to lithium ions is the surface hardening of the glass and of the ceramic bodies. The employment of lepidolite (lithium-potassium-aluminium-rubidium fluosilicate) has led to effects of this kind. It has been established that the influence of beryllium or lithium brings about an increase in the surface hardening of the order of 20%.

Vitrifying effect

The vitreous state is characterized by the presence of cations (Si) of small dimensions, with three or four neighbouring oxygen atoms. The silicon-oxygen bonds are strong and prevent activation due to temperature increase which might allow for passage from the vitreous state to the crystalline state. The silicon cations are rather widely separated one from the other with the result that only the apices of the polyhedra are held in common, *i.e.* the oxygen atoms which constitute the apices of the tetrahedra as noted previously. Only three of the tetrahedral apices are held in common, which contributes to the stability of the three-dimensional structure and explains the characteristics of high viscosity and conchoidal fractures of glasses and allows one to foresee structures based on SiO_2, GeO_2, P_2O_5, As_2O_5, Sb_2O_3, V_2O_5, Nb_2O_5, Ta_2O_5, etc.

Glasses are ordered solids in which the arrangement of the atoms corresponds to a ' long-distance ' order. The effect of lithium (and of beryllium) caused by the high value of the field produced by their ions is a tendency towards devitrification, which explains why glasses with a high lithium content are unknown. The ions which stabilize glasses are ions of large size and low valency, such as potassium. This, however, is true only for the glasses based on silica. For the glasses based on phosphates, it has been established that $LiPO_3$ is a stabilizer whereas KPO_3 is not. In the case of enamels, ceramics and ordinary glasses, large proportions of lithia do not cause devitrification and even exert a stabilising effect because of the presence of phosphates and probably, too, of lead and aluminium salts. In particular, glasses and ceramics of low melting point may contain lithia and still show in spite of that noticeable variations in composition without the appearance of devitrification phenomena.

This slightly surprising aspect of the characteristics of lithium is attributable, according to some writers, to the action of ions with ionic fields differing widely one from the other and whose resultant action would be stabilizing influence in the glasses. The tetrahedral networks (silica) or polyhedral networks (phosphate) subjected to electrostatic attractions become deformed. These deformations would prevent the rearrangement of the ions in an ordered lattice, analogous to that of the crystalline system. The action of the strongly polarizing lithium ion linked with that of a feebly polarizing potassium ion has the effect of stabilizing those glasses whose composition is the practical limit of the vitreous condition.

It is very often sought to lower the melting point of vitreous and ceramic substances. The operative mechanism allowing this result to be obtained has often been the subject of discussion. It has been established that a certain composition of phosphate glasses corresponds to a minimum value of the softening point. One can account for these results by noting that for compositions of very high viscosity the viscosity of the lithium-based glasses is higher than that of the glasses based on sodium or potassium.

It has also been observed that the softening power of lithia is not equally marked in the porcelains of high silica content as in the enamels of low fusion point. But even in the case of refractory porcelains a distinct lowering of the fusion temperatures has been established with lithium additions.

Expansion coefficient

The influence of lithia on the dilatation of ceramic substances is well known. Already in 1934 the following values for the expansion coefficients were published: Li_2O $4{\cdot}9 \times 10^{-7}$; Na_2O $4{\cdot}18 \times 10^{-7}$; K_2O $3{\cdot}4 \times 10^{-7}$.

From these coefficients one deduces that, if the molar effect is considered, the result of substituting lithia for soda makes for a reduction of the dilatation. It is this property which makes possible the formulation of glasses of low expansion and which can also permit, by means of judicious additions, the equalization of the expansion coefficients of enamels with those of the metals to be enamelled.

Conclusions

Metallographic study of alloys on the one hand and the investigation of silicates and ceramics from the physico-chemical point of view on the other has extended the field of our knowledge in these different areas. Consequently, new applications for lithium and its compounds have appeared which presages a favourable future development of the lithium industry.

The atomic mechanisms of fracture

Prof. N. J. Petch (University of Leeds) will give a lecture on ' The atomic mechanisms of fracture ' at the Institute of Metals, 17 Belgrave Square, London, S.W.1, at 6.30 p.m. on Thursday, May 28, 1959. The lecture will take the form of a report on a conference of the same title recently held at Swampscott, Mass., under the auspices of the U.S. National Academy of Sciences. Visitors will be welcome, and no tickets are required.

Annealing plant for South America

Houlder Brothers' *Swan River* is now making its maiden voyage to South America carrying in its holds a considerable proportion of a £500,000 annealing plant for the Sociedad Mixta Siderurgia Argentina. This plant, built by the Incandescent Heat Co. Ltd., Smethwick, will anneal 300,000 tons of steel a year. The furnaces are supplied as packaged units completely assembled in Great Britain.

Metallography

Electrolytic polishing of specimens

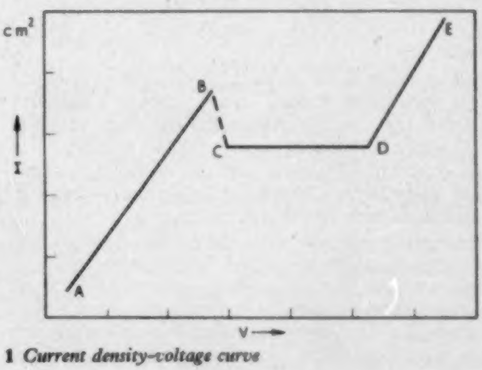
THE PRELIMINARY MACHINING TREATMENT of test specimens for metallographic investigation results in considerable structural changes in the surface layers and may even affect layers down to considerable depths. One function of the subsequent polishing treatment is to remove these destroyed or deformed layers. During the last 25 years, electrolytic polishing and etching has been developed and attains surface polish by the dissolution of the surface metal under the influence of an electric current when the specimen is made the anode in the circuit. Etching of the surface for laying bare the metallic structure can be effected in the same manner in one operation.

Data concerning electrolytic polishing and etching have been published in the technical literature for a large number of alloys, particularly for homogeneous 'mixed crystals,' *i.e.* solid-solution alloys. The attainment of perfectly polished surfaces is frequently complicated by the presence of non-metallic inclusions and other phases. Physical inhomogeneities, cavities, etc., also prevent the attainment of perfectly polished surfaces.

The condition of metallic surfaces obtained by electrolytic methods is governed by the rate of dissolution at different points of the surface. As a rule, elevated areas are dissolved in preference to depressions, while dissimilar structural constituents of the surface are also dissolved at varying speeds. It is thus evident that, while the solvent action of the electrolyte tends towards the flattening of a surface, it also induces a profiling action on the surface in accordance with structural arrangements. Due to the superimposition of these two opposite trends the resulting surface conditions are not generally favourable to metallographic observation; it is therefore necessary to suppress the profiling effect by concentrating the solvent action on materially different structural constituents exhibiting differing solvent speeds, or on chemically uniform constituents of different crystallographic surface areas.

In the case of the anodic process it is possible by proper selection of the electrolyte and suitable operating conditions to suppress either the profile-controlled or the structure-controlled dissolution in order to obtain the surface conditions required in each particular case. The way in which the latter depend on the operating conditions may be seen from a current density-voltage curve. If the voltage applied to the electrolytic cell is steadily increased, the current density does not grow in proportion but behaves as in the schematic curve, fig. 1. This curve clearly exhibits four different ranges which are characteristic of the different surface conditions obtained. A polished surface prevails within the range CD of the curve, the quality of the surface improving as a rule with increasing voltage up to point D. Due to gradually increasing gassing, the surface obtained within the range DE usually exhibits a pitted appearance. When starting with a polished surface, increasingly stronger etching of the grain area is obtained with increasing current density along AB, while in the range BC grain border etching is frequently observed. Otherwise this range is but little defined because of strong fluctuations of the electric values, which also explains the fact that differing surface conditions may prevail within this range.

In special cases the shape of the current density-voltage curve may depend not only on the type of metal treated and electrolyte employed, but also on a number of secondary factors such as temperature and concentration of the electrolyte. In such cases the operating values required for a certain surface condition are strongly dependent on these factors. The resistance of the external circuit



1 *Current density-voltage curve*

and of the electrolyte are also of considerable influence. The greater the resistance, the less pronounced becomes the horizontal range of the current density-voltage curve. Increases in the effective anode area operate in a similar manner if the latter is no longer small relative to the cathode area; thus the degree of roughness of the anodic surface has to be taken into account. Another factor of considerable importance is the convection current occurring within the electrolyte.

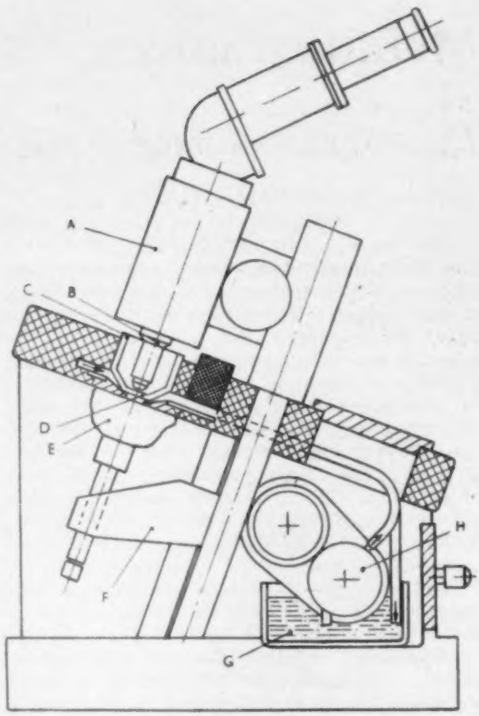
It is due to influences of this type that, with the usual simple arrangements, satisfactory results can be obtained only if the work is based on long experience and on thorough theoretical and practical knowledge of the electrolytic polishing processes.

Reliable electrolytic polishing and etching for routine examination is rendered possible only by the development of a number of devices by means of which the most important of these secondary factors can be kept constant. Such developments include the fixing of the size of the surface to be treated, for instance by covering the metal specimen with a non-conducting screen. Size, shape and position of the cathode as well as the resistance ratio are also stabilized by instruments, so that polishing and etching of specimens can be carried out by less experienced laboratory assistants. Difficulties of remaining variables can be surmounted if the surface of the specimen remains under permanent microscopic control during the electrolytic polishing process. A combination of an electrolytic cell with the 'Epignost' microscope, developed by VEB Carl Zeiss, Jena, enables permanent observation and control of the metal surface during the polishing and etching process, and the attached 'Miflex' camera gives a photographic record.

The equipment is shown schematically in fig. 2. The metal specimen is pressed from below against a non-conducting screen with circular opening (6 mm. dia.), while the surface of the specimen is observed through the electrolyte from above. The objective is protected by a dish, serving as cathode, whose lower opening is closed by a plane-parallel glass plate.

The shape of the cathode, in connection with the correspondingly shaped screen, ensures a laminary flow of the electrolyte over the specimen required for satisfactory polishing as well as uniformity of the electrical field acting on the specimen surface. The electrolyte is contained in a vessel located in the rear section of the instrument.

A pump conveys the electrolyte through the electrolytic cell at controlled flow velocity. Observation of the metallic surface with polarized light is possible at magnifications of up to 200: 1. The 'Epignost' microscope employed in this apparatus has top illumination and may equally well be used



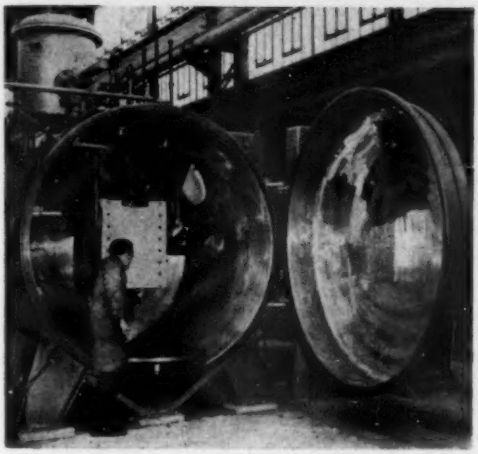
2 *General arrangement of electrolytic polishing apparatus*

A Microscope for top illumination
B Objective
C Cathode
D Cathode window
E Metal specimen
F Specimen support
G Electrolyte
H Pump

for other microscopic observations requiring top illumination.

The electrical equipment includes a separate power pack (220 V. a.c.) permitting the continuous adjustment of the d.c. voltage in the electrolytic cells within the ranges of 0 to 15 V. and 0 to 60 V. The unit is designed for a maximum current of 1 amp., permitting anodic current densities of up to about 400 amp./dm.^{2}

A series of devices permits reliable and comfortable utilization of the apparatus. The specimen support is designed in such a manner that optionally shaped specimens of up to 100 mm. dia., and up to a height of 30 mm., can be securely fastened. The elastic design of the head of the support permits the specimens to be removed without releasing the clamping screws or, if other parts of the specimen surface are to be treated, to displace the specimen accordingly.



Vacuum melting

The picture shows the new 600-lb. Wild-Barfield/NRC high-frequency induction-melting furnace recently installed at the Sheffield works of Jessop-Saville Ltd.

THE PROCESS OF VACUUM MELTING has opened up new horizons for the study and production of a new range of metals and alloys which essentially necessitate melting in the absence of air. Well-known examples of these metals are titanium and zirconium. It has, however, also been found that the vacuum melting process considerably improves the characteristics of many existing steels and enables the production of new alloy steels which cannot be made by any other method.

Turbine and compressor-disc materials used in gas-turbine aircraft engines must be virtually free from non-metallic inclusions. Vacuum melting can not only ensure this but also provides the designer with enlarged scope for even more highly stressed conditions. This freedom from non-metallic inclusions also ensures that the transverse ductibility of forged discs is improved. Tensile tests on vacuum-melted 12% chromium steel discs have for instance given elongation values four times greater than those obtained on discs made from air-melted material.

In ball-bearing and ball-race steels it is particularly important that there is freedom from non-metallic inclusions which might give rise to premature failure.

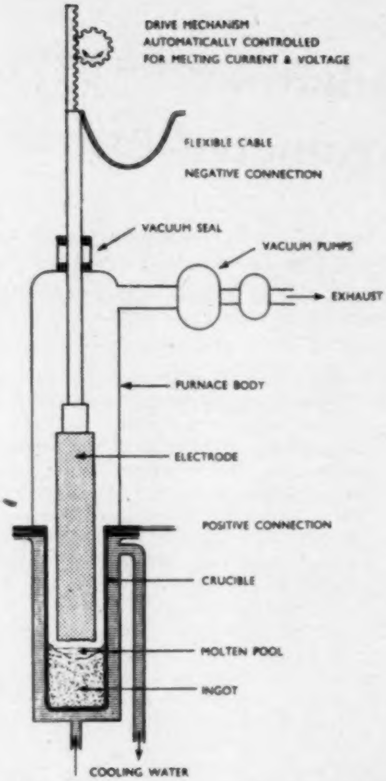
Vacuum melting reduces the total gas content of the metal. Tests have shown that with air-melted steel remelting in vacuum reduces the total oxygen, hydrogen and nitrogen content of the steel from 600 p.p.m. to 200 p.p.m. This feature of the process is particularly useful in the production of stock for precision castings or for remelting prior to precision casting, for in this way the undesirable blow holes and gas pockets can be obviated. The production of certain steels with low hydrogen content minimizes the need for long immunization heat treatments necessary to avoid the danger of hair-line cracking.

Induction vacuum melting has made possible the production of alloys which, owing to the presence of elements which readily oxidized, could not be produced by conventional air-melting methods. This new technique now opens up fresh fields in the development of high-temperature materials. One such alloy, Jessop G64, contains high percentages of aluminium and titanium and can only be made satisfactorily in a vacuum-melting furnace. It has excellent high-temperature properties and is being assessed for stator and turbine blade applications.

The advent of nuclear power plants has posed further problems for the metallurgist in the demand for new materials. One of these is zirconium, which can only be produced by vacuum melting.

In many nuclear applications it is essential that certain tracer elements in steel be reduced to an absolute minimum. The vacuum-melting technique permits close control of the chemical composition of every melt and enables certain elements to be completely removed and others kept to the specified minimum.

Two methods adopted by Jessop-Saville Ltd., Sheffield, for vacuum melting are the consumable-electrode arc-melting process and the high-frequency induction-melting process. Early in 1956, Jessops put a vacuum melting plant into full-scale operation. The melting furnaces were of the



2 *Simplified schematic of the Heraeus consumable-arc vacuum-melting furnace*

The consumable-arc melting furnace

The melting furnace consists of a large vacuum-tight vessel evacuated by pumps which are capable of handling large volumes of gas at high vacuum (fig. 2). The actual melting is carried out in the copper crucible which forms the lower half of the furnace.

An electrode is placed inside the furnace where it is welded on to the feeder rod, under high-vacuum conditions. The electrode can then be driven up or down, to control the melt, by applying drive to the feeder rod. This feeder rod also carries the melting current, through sliding vacuum seals, from the electrical busbars down to the electrode.

The melt is started by striking an arc between the bottom of the electrode and a small charge placed at the bottom of the crucible. The heat generated by the arc provides sufficient heat to melt the tip of the electrode. Molten metal sprays down to form a pool, which when solidified, forms the ingot. As the molten pool is only of small dimensions, great care must be taken to ensure that melting conditions are kept constant throughout the melt.

A view of the melt is projected on to the melting desk alongside the many electrical gauges. From these, the melting operator is able to assess the furnace conditions and make any necessary modifications to control the melting to a rigid specification.

The furnace components—pumps, valves, etc.—are actuated remotely from a control cabinet. There is provision for automatic operation of all vacuum equipment, so that, when the furnace is closed, evacuation is taken through all its stages entirely without supervision. This automatic system also safeguards the vacuum equipment in cases of component failure. For safety, the arc current is interlocked to all operations which, if faulty, could lead to dangerous conditions. A section of the cabinet is given entirely to indication of possible breakdowns so that rapid rectification can be made.

An electrical control unit drives the feeder rod as required by the melt. Arc gaps can be maintained within fine limits when using this unit at maximum sensitivity, and it is possible to apply a current of 18,000 amp. to the electrode.

The vacuum equipment is capable of holding melting pressures below one micron. In this pressure range, the arc is very stable. There are two pumps fitted for the final evacuation of the furnace, a roots and a booster pump. Their combined speeds are 4,000 litres/sec. for air and 10,000 litres/sec. for hydrogen.

Titanium ingots range from 9 in. dia. and 120 to 420 lb. through sizes 12, 16, and 20 in. dia. to 24 in. dia. exceeding 2½ tons in weight. The plant is capable of producing zirconium ingots, but it is likely that initial production will be confined to ingots up to 800 lb. in weight. Steel ingots up to approximately 3 tons in weight can also be produced in the same sizes.

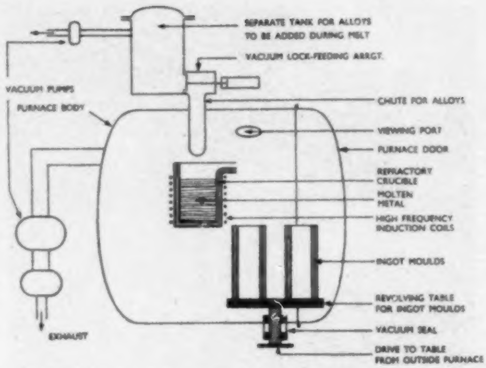
Particle hardening

The strength of most alloys used as structural materials depends on the presence of particles of other phases dispersed throughout the metal. Understanding of the strength of particle-hardened alloys has recently been advanced by a study, carried out by the General Electric Research Laboratory, New York, employing novel magnetic measurements. These techniques can magnetically determine the sizes, shapes and number of ferromagnetic particles present in an alloy, even though the particles may contain only a few thousand atoms each. Such particles are far too small to be seen optically.

The measurements indicate that there exists a critical size of particle for which the hardening of the alloy is a maximum. They also have determined the change in shape of these submicroscopic particles during deformation of the alloy.

consumable-electrode type capable of producing titanium ingots with a diameter up to 20 in. and 1 ton in weight. Some time prior to this a small 20-lb. vacuum induction-melting furnace had been installed for research development work.

It was realized that with increasing demand for these new materials the plant would not satisfy all requirements particularly for the larger forgings, and the decision was made to increase production facilities. The new Heraeus consumable-arc melting furnace has now been installed and is fully operational. This is capable of melting titanium ingots up to 24 in. dia. and more than $2\frac{1}{2}$ tons in weight. Also recently installed and fully operational is a new 600-lb. Wild-Barfield/NRC high-frequency induction-melting furnace. Each of these furnaces is of the largest type in this country and in combination provides the largest operational vacuum-melting plant outside America.



1 *Simplified arrangement of the 600-lb. Wild-Barfield NRC high-frequency vacuum induction-melting furnace*

The vacuum induction-melting unit

The unit is designed for semi-continuous operation, provision being made to accommodate sufficient ingot moulds for several heats on the rotary mould table, and for charging the furnace through a bulk charging hopper without breaking the vacuum in the melting chamber.

The principal unit of the installation is a horizontal vacuum chamber constructed of stainless steel approximately $7\frac{1}{2}$ ft. in diameter by 9 ft. long. The end of this chamber is sealed by hinged door and the whole of the chamber and door is water cooled by copper coils, brazed to the outside of the unit. The chamber contains the high-frequency induction-melting coil which is designed to tilt about the pouring axis. Immediately in front of and below the furnace there is a rotary mould table which allows several ingot moulds or castings to be poured from one melt. Provision is made for the observation of all stages of the process through three observation windows, each equipped with shields and wipers (fig. 1).

External controls are provided for the following operations: (1) Bridge breaker for breaking top layer of unmolten metal in the crucible; (2) immersion thermocouple pyrometer for temperature measurement; (3) sampling device which can be extracted through an air lock without breaking the main tank vacuum for compositional control during melting; (4) sighting tube for optical pyrometer readings; and (5) internal light assembly for illumination of the tank interior.

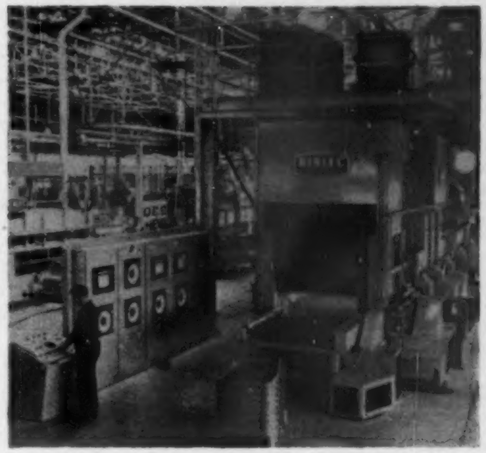
A cylindrical chamber, situated on top of the horizontal melting chamber, contains the alloy charging mechanism, consisting of a 2,200-cu. in. bulk charging hopper, holding 300 lb. of material, and four smaller hoppers each of 90 cu. in. and holding a further 12 lb. of alloys each. Both bulk charge and alloys are delivered to the crucible by a vibrating feeder through a 6-in.-dia. vacuum lock. Alloy buckets are individually tripped by solenoids operated from the control panel. The vibrator feeds into a chute which swings over the crucible and an interlock is provided which prevents the vibrator from operating unless the chute is in position. The whole of this chamber may be refilled without breaking the vacuum in the main tank by closing the vacuum lock. A special pumping line is provided to evacuate this chamber after it has been recharged with material.

The pumping system is designed to handle the gases from 600 lb. molten charge during melting, purifying and alloying. The pumps have the necessary capacity for disposal of the gases as they are given off from the melt. Pneumatic operation is provided for all the vacuum valves used during the pumping cycle. The vacuum system consists of a large 16-in.-dia. high-vacuum manifold and a 6-in.-dia. rough pumping line connected to the end face of the melting chamber to enable rapid and complete evacuation of the chamber. This combined system will pump the furnace chamber from atmospheric pressure to a pressure of one micron Hg in 15 min.

Vacuum gauges measure the furnace tank pressure from one micron to atmospheric pressure. The vacuum instruments consist of one alphatron gauge and a five-point thermocouple vacuum gauge.

The power supply for the melting is a 200-kW. motor alternator set working at 400 volts and 3,000 c./s.

The furnace will be used for melting iron, nickel and cobalt-base alloys.



Cyclic annealing of forgings

In the new Birlec cyclic-annealing furnace installation at Caterpillar Tractor Co. Ltd., several stages in the complete heat-treatment cycle, hitherto carried out separately, are performed in automatic succession on a pre-determined time/temperature schedule.
Completely automatic in operation, the furnace incorporates a number of important work-handling mechanisms

THREE CONTINUOUS electric furnaces by Birlec Ltd. are included in the production heat-treatment plant at the Glasgow factory of the Caterpillar Tractor Co. Ltd. One of these furnaces, designed for the cycle-annealing of forgings, is of special interest.

The furnace is used mainly for the heat treatment of forgings prior to machining and final heat treatment. This involves two annealing cycles, a normal anneal, *i.e.* heating to an austenitizing temperature and slow cooling, and an isothermal anneal in which the work is fast-cooled to an intermediate temperature within the range 600—700°C., held there for a specified time and subsequently slowly cooled to discharge. A third heat-treatment cycle is possible and involves fast cooling from the austenitizing temperature to temperatures in the region of 350—400°C. in a period of 20 minutes.

The equipment consists of a furnace with a heating chamber, fast-cool chamber, holding chamber, water-cooled chamber and a spray quench section, the charge being conveyed through the whole by a series of driven rollers. The rollers are driven by a Carter unit with a variable gear box, from the output shaft of which a chain drive is connected to a line shaft.

With a usable conveyor width of 42 in. and a loading height of 22 in. above the rollers, the furnace is capable of an output of 2,000 lb./h. Work is carried on cast nickel-chromium alloy trays 42 in. square, loaded to about 2,000 lb. each. Certain sections of the roller track can be accelerated from normal speed to fast speed, to transfer trays quickly from one section to the next.

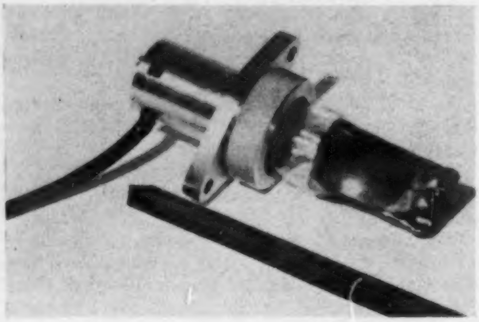
Having heating elements, totalling 475 kW., divided into six separate zones, the furnace is controlled by Honeywell-Brown instruments, all six zones being controlled separately by indicating controllers. For a permanent record, three point recorders for the heating and slow cooling chambers and a single point recorder for the fast-cool chamber are provided.

Insulated doors are fitted at the charge end of the furnace and at the end of the water-cooled section, with an intermediate door between the heating and fast-cool chambers. All the doors are automatically motor operated. A large axial flow fan is fitted in the roof of the fast-cool chamber and is automatically controlled for the varying cycles. This fan works in conjunction with a series of air cooling tubes, inserted into the side wall, which are fed by means of a blower mounted externally above the furnace.

The spray chamber, built of non-corrosive material, has water sprays in the roof and a tank reservoir beneath the rollers. The water is recirculated by a thermostatically controlled pump mounted at the side of the chamber. The water-cooled section is of the double jacketed type with the water circulating through the side walls and hearth. The roof has a removable water-cooled tank sitting in a bitumen seal.

Loading operation

The operator loads a charged tray on to the furnace charge table, pushes it forward until the leading edge operates the charge table flap switch. The tray waits in this position until the tray immediately inside the charge door of the furnace has moved forward to permit charging of new tray. As soon as the space is available, the charge door opens and the fast drive is automatically started to move the tray from the charge table into the



Radiation pyrometer

A general view of the pyrometer head of the new G.E.C. instrument

THE WEMBLEY RESEARCH LABORATORIES of the General Electric Company Ltd. have developed a radiation pyrometer for monitoring the surface temperature in an induction-hardening process. The instrument consists of a thermopile specially constructed so as to give an electrical output substantially independent of ambient temperature, over a wide range of source temperature.

The device may be used with a radiation collecting probe, or with an aperture stop—or system of collimating stops—in the path of the incident radiation. Successful use has been made of a fused silica probe in an induction hardening and tempering process when the source area was small and was normally obscured by quench oil, spray and smoke.

The pyrometer is not an absolute measuring instrument, and requires calibration in any particular application. Once calibrated, however, it has been found very consistent, and lends itself readily to the following applications:

With probe: (*a*) Hardening and tempering by a progressive method; (*b*) induction melting; (*c*) furnace charge temperatures; (*d*) temperature measurements where the source is obscured by intervening structures, and (*e*) temperature of liquids.

Without probe: (*a*) strip and sheet rolling; (*b*) extrusion temperatures, and (*c*) flame temperatures.

Principle of operation

A target body is mounted inside a cavity in an aluminium block, and is almost completely enclosed. Because of its high thermal diffusivity and thick wall the cavity may be considered at uniform temperature.

A narrow pencil of heat radiation is allowed to fall on the target through a small aperture in the cavity wall so that the temperature of the target is raised above the temperature of the cavity. The device is normally stopped down so that the temperature difference is only a few degrees Centigrade. The steady temperature rise of the target above the cavity is then a measure of the amount of radiation absorbed by the target and indirectly of the temperature of the source of radiation.

The temperature differential of the target with respect to the cavity due to a given source of radiation changes only slowly with the temperature of the cavity itself, providing the temperature of the source exceeds a few hundred degrees Centigrade. For example, a pyrometer of this form changes its target temperature differential less than 5% for an ambient change from 15 — 50°C. when viewing a source at 300°C. Due to the sharply rising response of the pyrometer with source temperature this represents an error in indicated source temperature of less than -6°C.

The output of the instrument naturally depends on the effective aperture of the pyrometer and the disposition and surface condition of the source of radiation. With full aperture the instrument responds to radiation from a cone of about 40° included angle although the peak sensitivity occurs within a cone of 10° included angle.

Usually the instrument is stopped down to give about one millivolt of output which may be connected to a millivoltmeter or light-spot galvanometer. The response rate of the system in this case depends on the millivoltmeter, the response of the thermopile itself being very rapid. In fact, it is estimated that the thermal time constant of the pyrometer itself is of the order of 1/10 sec.

When the source is likely to be obscured by smoke or spray, or is otherwise inaccessible it is convenient to fit a radiation transmitting probe between the source and the pyrometer. Probes have been made of polished rods of fused silica, ¼ in. dia. and used successfully up to 12 in. length.

It is sometimes necessary to shield the air-to-silica surface of the probe from contamination by condensates so that the transmission properties of the probe are undisturbed. A fused silica sheath has been used for this purpose, concentric with the probe and fused to it at the source end.

Plant generation of acetylene gas

ALL THE ACETYLENE used for flame hardening by Alfred Herbert Ltd. at their Edgwick Works, Coventry, is generated on their own premises, the installation being specially built to supply acetylene for this purpose. Acetylene is also used for local flame softening which is sometimes required before such operations as drilling.

The installation comprises four Model 200 'Aut-O-Cet' generators, supplied by Weldcraft Ltd., Purley Way, Croydon, Surrey. Three are normally in use, with one held in reserve, although occasionally it is necessary to run all four at the same time in order to provide sufficient acetylene during peak loads. One part-time operator is employed in the generator house, and is responsible for draining the generators, charging with calcium carbide, operating the sludge filter press and general maintenance work.

The 'Aut-O-Cet' automatic-pressure generator is designed to produce high-grade acetylene for workshop use, simply and efficiently. It gives the user the same efficiency as bottled gas with pressures up to the generally permitted maximum of 9 lb./sq. in., plus higher flame temperatures at lower cost. It has been tested and approved by H.M. Home Office for use, in suitable premises, at a working pressure of 15 lb./sq. in., and is the only generator which has passed this exacting test.

Completely automatic in operation—gas is only generated when the blowpipes are in use—the generator prevents wastage and can be shut off for weeks without deterioration of the carbide or the evaporation of water.

Operating principle

'Aut-O-Cet' generators are of the carbide-to-water type, and consist essentially of a cylindrical water tank to the top of which is fitted the removable carbide hopper. The hopper is filled with granulated carbide, the tank with water to the level indicated, and the hopper placed in position.

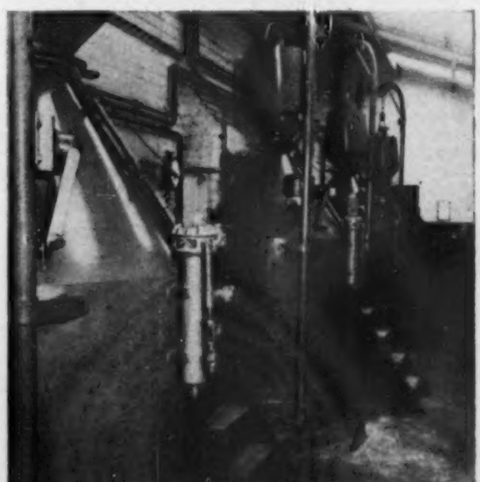
Generation is started by lifting the feed lock handle on top of the hopper. This drops the feed rod, allowing carbide to fall into the water and generating acetylene. As the pressure of the generated gas increases, it lifts the diaphragm and feed rod, shutting off the flow of carbide so that no further gas is generated. Similarly, as the gas is drawn off by the operator, the pressure inside the tank falls and more carbide drops into the water.

The gas pressure against the diaphragm regulates the feed exactly and permits only sufficient carbide to drop into the water to replace the gas drawn off. If the outlet valve is closed the pressure will shut off the flow of carbide and generation will cease immediately. The action is automatic and continues until the carbide is exhausted, or the feeding mechanism is locked by pulling down the handle.

Pressure adjustment can be effected by means of the wing nut on top of the carbide hopper, the screw being fitted with a collar so that the legally permitted maximum pressure cannot be exceeded. The acetylene passes from the generator through a safety valve which opens if the pressure in the tank exceeds a predetermined figure and, in order to ensure that it does not become blocked or inoperative, this safety valve is also automatically opened by the removal of the hopper for re-charging.

The gas from each generator is then piped from the safety valve to a pair of flashback arrestors (hydraulic valves) fitted in series. These are designed to prevent a backfire from reaching the generator and possibly causing serious damage. They are installed in a small separate compartment of the generator house, and from these the gas proceeds through the main pipeline to the shop.

The sludge from an 'Aut-O-Cet' generator consists of 65% water, 30% hydrated lime and 5% miscellaneous solids, including carbon. Where



Installation showing the four acetylene generators. The 'flashback arrestors' (hydraulic valves) are in a separate compartment

furnace until it is stopped by a photoswitch, and the door is closed behind it.

The tray is then carried through the heating chamber at normal roller speed until it breaks the light beam of the photoswitch in front of the fast-cool section. This switch opens the door starting the fast-cool section high speed drive which moves the tray forward into the chamber until it is stopped by another photoswitch and the chamber door is closed behind it. When the door is fully closed the cooling blower and the axial-flow fan motors are started and run for a predetermined time.

Cooling cycle

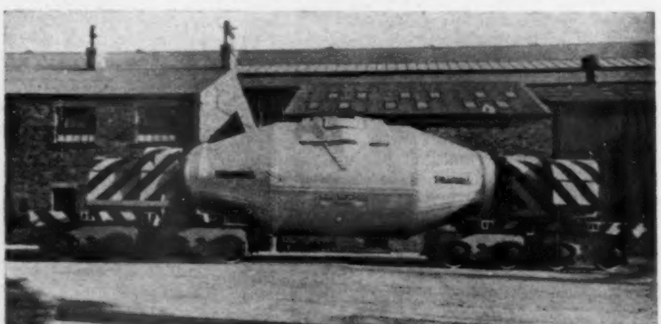
During the cooling cycle the charge continues to move forward at normal speed until the following tray operates the switch in front of the chamber door. When this tray is driven into the chamber the leading tray, which is almost out of the chamber, is driven at high speed towards the discharge door. The tray then travels at normal speed until it breaks the beam of the photoswitch in front of the discharge door. The door then automatically opens and the fast speed drive carries the tray clear of the furnace into the spray chamber where the leading edge operates a flap switch which stops the fast drive and closes the door. The sprays in the spray chamber then start automatically and run for a set time at the end of which the fast drive takes over and discharges the tray.

The second cycle has a similar sequence of operation except that the fast-cool section is made inoperative. Both cycles can, if necessary, be operated by a series of control buttons mounted on the control desk which also contains the auto-manual changeover switch, timer and indicating lamps which show the position of the trays within the furnace, *i.e.* whether or not the door approach switches are clear or about to operate.

The normal annealing cycle is used for medium- and high-carbon steels such as S.A.E. 1040 and S.A.E. 1080. In the main, the forgings thus treated are for such components as con-rods, levers and pawls which are hardened and tempered after machining. The advantages of this preliminary anneal are the obvious ones of grain refinement and machineability. These same advantages are obtained by the isothermal annealing, but the forgings thus treated are generally of heavier section and take the form of shafts and gear blanks. As would be expected, such components are ultimately carburized and hardened and the grain refinement helps in the attainment of uniform carburizing and in limiting distortion on subsequent quenching. The steels used are plain-carbon carburizing steels such as S.A.E. 1018 and low alloy carburizing steels such as S.A.E. 8720H and S.A.E. 8622. The forgings vary in weight from 10 lb. to as much as 250 lb. for a large gear.

The third heat-treatment cycle for which the furnace was designed involves air-blast cooling to much lower temperatures. Medium-carbon steels thus treated have mechanical properties somewhat lower than those which would be obtained by the more normal hardening and tempering procedure. However, since this involves only the single heat treatment it is obviously cheaper than hardening and tempering would be. Hardness values obtained are in the range 155—190 Brinell and the method results in a higher yield point than would be obtained by straightforward normalizing and yet maintains superior machineability. Also the microstructure obtained is more suitable for subsequent induction or flame hardening than that obtained by annealing or normalizing. A typical forging subjected to this treatment is a drive shaft of approximately 100 lb. weight and made from S.A.E. 1046 steel.

Britain's 180-ton hot-metal mixer car



One of three 180-ton-capacity hot-metal mixer cars for the Steel Company of Wales manufactured by Head Wrightson Teesdale Ltd., to the design of the Treadwell Co. of America, in conjunction with the International Construction Co., London. The ladle is electrically tipped by a motor through reduction gears engaging a gear on the trunnion at one end of the ladle. This is the largest hot-metal ladle car in this country, and the gross weight when fully loaded is approximately 380 tons, giving a 24-ton wheel load

the quantity involved is not great, the sludge can usually be disposed of through the sewage system, but this must be followed by flushing with clean water to prevent the sediment from accumulating and blocking the traps. Where local regulations do not allow this, it can be run into a pit and allowed to settle. The water can then be run off, leaving the residue of hydrated lime.

Purity and economy

Although the 'Aut-O-Cet' generator ensures that the acetylene is produced at a low temperature, nevertheless very small percentages of sulphur and phosphorous compounds are always present in the gas. If it is necessary for the gas to pass the silver nitrate test, these impurities must be removed by chemical purification.

A purifier is specially manufactured for this purpose and may be placed between the generator and the line so that the gas passes through it and is automatically purified. It consists of a steel vessel holding a loose galvanized container, for ease in filling, into which is placed a special purifying material, the essential constituents of which are iron compounds rendered porous and permeable by the addition of the natural form of silica, together with a powerful activating agent which imparts to the material the power of recovering its chemical activity without external assistance.

The choice of generated acetylene at Alfred Herbert Ltd., as opposed to acetylene in cylinders, was made only after many factors had been carefully considered. The relative costs of the two gases were analysed, and it was clear that the cost per cubic foot of generated acetylene, based on the amount of carbide used, was substantially less than that of dissolved acetylene. Further, acetylene cylinders have to be changed at frequent intervals and the handling of them, with the access for lorries which has to be provided, was costly and inconvenient.

The low cost of generated gas, plus its greater convenience, were the two points which influenced the choice of Alfred Herbert Ltd.

Radiation monitoring service

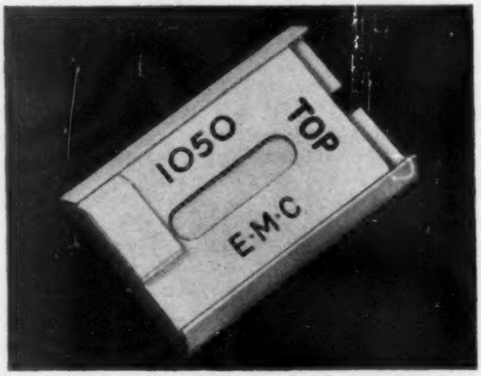
BARELY 30 YEARS have passed since the first general and everyday use was made of radioactive materials. Since the last world war, the use of radioactive materials has increased considerably and such materials are now being used in well over 100 different types of industrial operations, quite apart from medical and surgical applications.

Unfortunately, the effect on personnel exposed to radiation, which is neither felt nor seen, is not immediately apparent, and it is probably some time after a period of exposure before any effect becomes known, the length of time being dependent upon the type of radiation and the dosage. The results of over-exposure can be varied, some of the more serious being the possibility of impaired fertility, formation of mutations in the course of generations, radiological dermatitis, skin burns, cataract and initiation of cancerous growths. It is also possible for radioactive materials to be absorbed into the bone marrow and various organs of the body and so cause leucopenia and similar effects.

Though care will naturally be taken in the protection of personnel engaged in the vicinity of radiation, it is still desirable that there should be a constant local watch and check on the 'dosage' they receive.

Electronic Machine Co. Ltd., 41 Lodge Road, West Croydon, Surrey, have now formed a Radiological Division which is offering a complete radiation monitoring service to users of X-ray machines and other radioactive materials. The radiation monitoring service will supply a numbered monitoring film holder (designed by Dr. G. Spiegler, DR.PHIL., F.INST.P., F.R.P.S., formerly of the Royal Marsden Hospital), together with a film—one spare film being supplied at the same time for replacement at the end of the first week. The number of 'holders' is in accordance with the number of personnel for whom it is desired to contract.

At the end of each week the film is removed from the



'holder' and posted to the radiation monitoring service for processing, reading and recording, the spare film then being put into the 'holder' and a further film replacement is sent by the service on receipt by them of the first film for processing. Each film 'holder' is numbered, the number being allocated to one individual wearer.

In the event of a weekly or accumulative dose exceeding the recommended dosage as laid down by the International Commission of Radiological Protection, an immediate communication is sent to advise the safety officer or the principal of the organization concerned so that immediate steps may be taken to remove and give the affected person the necessary treatment and to also take necessary measures to avoid a further occurrence.

A staff of trained personnel and an advisory panel of physicians and physicists are available to investigate, on site, causes of excessive dosage and will advise on the safety measures to be taken.

EXHIBITIONS

This is the season of exhibitions, and both in London and other important centres, many interesting displays have and are taking place. To describe them all adequately is, unfortunately, not possible, so we have selected certain points of interest without any claim to be representative. Many individual exhibits of new plant and equipment will, however, be featured in future issues of this journal.

THE ENGINEERING, MARINE, WELDING AND NUCLEAR ENERGY EXHIBITION at Olympia, London, last month, showed the latest advances in every branch of heavy engineering, and featured displays by about 500 exhibitors. The Exhibition was opened by Sir Edward W. Thompson, M.A., J.P., honorary president of the Exhibition and president of the British Engineers' Association.

Forging activities formed the centre-piece of **Steel, Peech & Tozer's** display on the stand of the United Steel Companies Ltd. A large colour picture of the company's 2,000-ton forging press was supplemented by small-scale models of 21 types of forging to give an idea of the plant's capacity. There were also coils of hot and cold-rolled strip together with finished products made by customers, a range of rolled-steel rings to show the various sizes rolled and a display of nuts, bolts and machined parts made from the company's bar-mill products.

Cold extrusion of steel

Industry is becoming increasingly interested in cold extrusion methods for manufacturing steel components, the principal advantages being lower cost and improved mechanical properties. **The Mechanical Engineering Research Laboratory**, DSIR, featured these new methods on their stand.

A good deal of basic information on the extrusion characteristics of various steels is now available to help firms wishing to produce particular components. It includes data on the relation between reduction of area and extrusion pressure and on the limitations imposed by the maximum permissible stress in the punch. Examples of the data available were displayed.

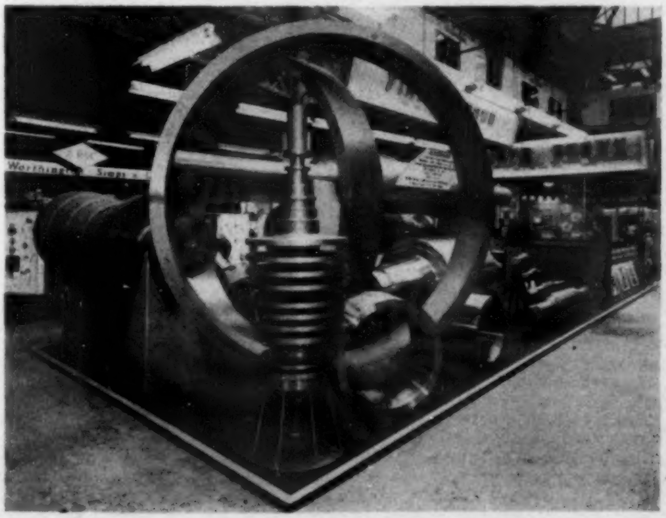
Dramatic improvements and savings which have been effected by a number of firms through the use of gas were illustrated by photographs and captions at the **Gas Council's** stand. The general theme was research and development.

A fuel cut-off device for use with flame arrestors (developed jointly by the West Midlands Gas Board and Ether Ltd. who market it) was shown.

Cut-off device

The device consists, essentially, of a sensitive thermocouple moving coil relay and suitable micro switch. In the event of a flame being established at the flame arrestor a thermocouple is heated, the moving coil relay contact is broken and the relay operating the micro switch is de-energized. The micro switch contacts open, a solenoid valve is de-energized and closes, shutting off the mixture supplied to the burners. The valve cannot be reopened until a reset button is manually operated. After testing for a total of 2,000 operations at one minute intervals it was shown that there was no deterioration or damage to the thermocouple of the flame arrestor.

Five **I.C.I.** Divisions, including Marston Excelsior Ltd., an I.C.I. subsidiary, exhibited.



Thos. Firth & John Brown Ltd. exhibited over 120 tons of forgings, including a range of drop forgings by its associate company, the Firth-Derihon Stampings Ltd., at the Engineering, Marine, Welding and Nuclear Energy Exhibition, where the accompanying photograph of the company's stand was taken

The exhibits of this latter company comprised wrought and fabricated titanium, products for nuclear engineering, heat transfer materials and specialized products.

Of particular interest in the titanium section were exhibits featuring platinized titanium anodes (including copper-cored rod) for the cathodic protection of vessels, pipelines and jetties. Titanium turbine blades, power station condenser tubes and funnel exhaust scrubbing equipment were also shown.

The 'new' wrought metals such as zirconium, titanium, niobium and vanadium were seen in the nuclear engineering section.

Welding

The largest range of a.c. arc-welding equipment in the U.K. was exhibited by **English Electric Co. Ltd.**, and in addition the company introduced two new equipments and further additions to its range of electrodes.

The outstanding exhibit was the LWAD. 600 welding rectifier which offers the choice of two outputs, namely, 95—520 amps d.c. of either polarity or 116—624 amps a.c. The equipment is mounted on three rubber-tyred wheels, is extremely manœuvrable and is the answer to problems of welding supply where both a.c. and d.c. are required.

A flash welder was exhibited by **Fuller Electric Ltd.**, member of Hawker Siddeley Industries Ltd. While the machine, which is rated at 150 kV. at 50% duty cycle, welds standard boiler tubing, it is also specially designed to weld chrome molybdenum tubes and finned tubing. Internal flash is automatically reduced by a special process during the welding operation. The equipment allows for the automatic heat treatment of the work-piece after welding whilst still clamped in the machine.

The only British designed and manufactured equipment for the automatic welding of vertical joints was demonstrated in operation on the stand of **Quasi-Arc Ltd.** The process is given the name 'Vertical Unionmelt Welding' and is equivalent to the Russian process known as 'Electro-Slag Welding.'

Vertical unionmelt welding involves the formation of a molten pool of metal between the edges of the vertical plates to be welded, the sides of the pool being retained by water-cooled copper moulds.

Typical applications of the new process are to the welding together of large forgings, or of castings of forgings, and other work which has to be welded in the vertical position.

Electro Mechan-Heat Ltd. showed a range of equipment for resistance welding. Two of the machines shown were new to Britain and are now being built by Electro Mechan-Heat under licence to Electromécanique, Brussels.

On show was the fully Automatic Mitre Flash Butt Welding Machine of 90 kVA. capacity, suitable for the manufacture of aluminium, brass or steel sections. The 'up-set' and 'forging' pressures are oleo-pneumatically controlled and all settings are easily readable.

Electro Mechan-Heat is a member of the Guest, Keen & Nettlefolds Group of Companies.

Murex Welding Processes Ltd. showed a range of products ranging from hand-welding electrodes to automatic welding machines, electrodes and fluxes. Considerable attention was devoted to automatic equipment for the welding of mild steels and stainless steels. Some of the latest models from the comprehensive range of Murex welding power packs, mobile equipments and welding accessories were also on view.

FACTORY EQUIPMENT EXHIBITION

The Factory Equipment Exhibition was opened by the Minister of Power, Lord Mills, at Earls Court, London, last month. More than 300 exhibitors showed equipment relating to materials handling, storage, heating and steam raising, ventilation and air conditioning, heat and sound insulation, product finishing and instrumentation. There were also workshop and packing equipment, production and stock control, drawing office equipment, safety and welfare, cleaning and maintenance, and factory building materials and systems.

A variety of workshop machinery and equipment was shown and also automatic measurement and control instruments including flame failure and safeguard instruments, smoke density meters and moisture meters.

Two interesting exhibits on the stand of the D.S.I.R. were contributed by the **British Iron and Steel Research Association.**

One of these showed an optical method for measuring the dimensions of hot forgings, hot rolled bar, or other hot steel sections at a distance. The principle of the system is that a telecentric lens-system is used to produce an image of the object to be measured so that dimensions of the image correspond to the 'projected' dimensions of the object.

The other exhibit concerned a development from the plant performance recorder, the ideas for which were published by BISRA two years ago, and which is now being built for instalment in a giant tyre factory in Russia. The factory is to be built by a consortium of British firms and the monitoring equipment is now being made by the Digital Engineering Co. Ltd., London. Some of the actual equipment for the Russian factory was shown.

The factory is to be erected near Dniepropetrovsk and is designed for the production of large numbers of tyres for cars, lorries, tractors and heavy earth-moving equipment. The entire process of tyre and tube making is to be monitored hourly and at the end of each shift, providing the production manager with a complete classified summary of his production of the various components.

Many applications of liquefied petroleum gases were shown by **Shell-Mex and B.P. Gases Ltd.** Models demonstrated the use of these gases for protective atmospheres during the heat treatment of metals, and an example of a modern muffle furnace was shown on this stand by **British Furnaces Ltd.** This firm's new gas-fired shaker hearth furnace is rated at 100 lb./h. output for clean hardening. The furnace has an operating range of 750—930°C., using either endothermic (RX) or exothermic (DX) atmospheres and is capable of giving light case treatment, or surface carbon correction with reduced output.

Ultrasonic and electrolytic equipment for the factory cleaning of parts prior to plating, painting and finishing were to be seen in operation on the stand of the **Electrical Development Association.**

Also to be seen on this stand was a cleaner providing a modified form of impact blasting using abrasive suspended in a liquid which is delivered to a blasting nozzle by means of a high-pressure circulating pump. The cleaner imparts a satin polished finish, down to 4 micro inches, depending upon the type of material being processed.

Corrosion Exhibition

Corrosion Technology's first corrosion exhibition was held in October, 1957, at the Royal Horticultural Society's Old Hall, when 54 manufacturers and suppliers of anti-corrosion products and services exhibited. The 1959 Exhibition, which was the second of these exhibitions,

was held in the R.H.S. New Hall last month and showed the products of nearly 80 firms.

Paints and plastics, coatings and linings, metals, cathodic protection, water treatment, fuel additives, industrial glassware and porcelain, corrosion prevention tapes, derusting tools, metal spraying and metal finishing processes, were some of the items on show.

Sir Owen Wansbrough-Jones, Chief Scientist of the Ministry of Supply, opened the Exhibition. The scientists of his Ministry have done, and are doing, notable work in corrosion technology and his support was particularly appropriate on this account.

FUTURE EXHIBITIONS

British Foundry Exhibition

BRITAIN'S FIRST national exhibition devoted solely to the foundry industry will be held in Birmingham this month. Between May 21-30 the city's Bingley Hall will house exhibits and displays of foundry plant, equipment and supplies.

Nearly 100 firms specializing in the manufacture and supply of foundry requisites will take part, and with many working exhibits the famous exhibition hall will take on the appearance of a big industrial plant. Special measures have been taken to enable furnaces to be used and molten metal to be handled, and leading British technical experts expect to welcome foundrymen from all parts of the world.

The exhibition is sponsored by the Foundry Trades' Equipment and Supplies Association Ltd. Mr. G. E. Lunt (managing director of Bradley & Foster Ltd., of Darlaston, Staffordshire), who is chairman of the Exhibition Committee and a former president of the Association, said: 'This exhibition has been under consideration for a long time, for it was felt that the resources, achievements and capabilities of the British foundry industry and its allied trades merited proper display under their own banner, and not merely as a section of any other trade exhibition.'

The exhibition will not be open to the general public, and admission will be by ticket or trade card presented at Bingley Hall between 10 a.m. and 6 p.m. each day with the exception of Sunday.

Details of some of the exhibits will be given in the next issue of METAL TREATMENT.

British Trade Fair, Lisbon

This exhibition will be held in Lisbon from May 29—June 14. The products of **English Steel Corporation Ltd.** (including Taylor Bros. & Co. Ltd., the Darlington Forge Ltd.) and its associated company, Firth-Vickers Stainless Steels Ltd., will all be featured on one large group stand.

Actual exhibits on view will include smaller sized products such as drop-forged aircraft and automobile parts, railway, coil and laminated springs, torsion bars, automatic couplers for railway rolling stock and mine cars, high grade carbon and alloy steels, engineers' cutting tools, permanent magnets, an exhibit of scale models of solid forged railway wheels, tyres and axles and one of model ships' sternframes, port and starboard shaft brackets and a 'Doxford' crankshaft.

In addition, an E.S.C. subsidiary, English Steel Castings Corporation Ltd., will be loaning for display on the British Iron and Steel Federation stand at the same Exhibition a 'Commonwealth' type one-piece cast steel bogie as supplied to New Zealand Government Railways.

Wild-Barfield Electric Furnaces Ltd. will be exhibiting a selection of equipment. The largest furnace will be a horizontal batch-type equipment Model HW1610, having a chamber 30 in. long with a door opening 16 in. by 10 in. Apart from the automatic temperature controller—which is of the wall-mounting pattern—the furnace is completely self-contained and all door mechanism enclosed. It is rated at 22 kW. and has a maximum operating temperature of 1,050°C.

Wild-Barfield are also exhibiting at the POZNAN INTERNATIONAL FAIR, June 7-21, and at the 5TH SALON DE LA CHIMIE, PARIS, June 16-30.

Associated Electrical Industries Ltd. will display illustrative products of the A.E.I. Turbine-Generator and Heavy Plant Divisions, and member companies, Metropolitan-Vickers Electrical Co. Ltd., Siemens Edison Swan Ltd., and A.E.I.-Gala Ltd. A.E.I.-John Thompson Nuclear Energy Co. Ltd. will also have an exhibit on the stand.

Vitreous Enamel Development Council

AT THE OFFICIAL OPENING of the Vitreous Enamel Development Council's new premises at 28 Welbeck Street, W.1, recently, Mr. K. Jones said that since the Vitreous Enamel Development Council came into being, just over two years ago, it had succeeded in establishing minimum manufacturing standards among its members.

Mr. Jones also spoke of the recent inauguration of the Enamel Advisory Service in London. This is a free information service to housewives and industrialists, set up to deal with the many problems encountered with protective coatings and finishes on domestic and industrial products. The service has now been extended, and advisory bureaux now exist in Glasgow, Cardiff, Birmingham, Manchester and Newcastle, shortly to be followed by a centre in Southampton. It is hoped to extend the service later on in the year, possibly to Belfast, Norwich and Aberdeen.

Mechanical engineering research laboratory

The Council for Scientific and Industrial Research announces that in future the Mechanical Engineering Research Laboratory at East Kilbride, near Glasgow, will be known as the National Engineering Laboratory. This is because the Council considers it desirable to emphasize the national character of the Laboratory which is part of the D.S.I.R. organization and is financed from public funds. It does not imply any change in the field covered by the Laboratory, which will continue to be concerned with problems of mechanical engineering.

The Council has also decided to set up a Steering Committee to look after the programme of the Laboratory. As a result of a recent review of the functions and activities of the Laboratory, the Council is convinced that, between the proper and reasonable activities of the universities and technical colleges on the one hand and research associations and private and nationalized industry on the other, there is an important place for a national establishment for research in mechanical engineering, mainly supported by public funds.

The object of the Laboratory is to establish the principles and extend the knowledge of mechanical engineering science so as to provide industry with the information it requires for the solution of its own particular problems.

The new Steering Committee will be under the chairmanship of Vice-Admiral Sir Frank Mason, K.C.B., M.I.MECH.E., M.I.MAR.E., who is a member of the Research Council and chairman of the outgoing Mechanical Engineering Research Board.

NEW PLANT

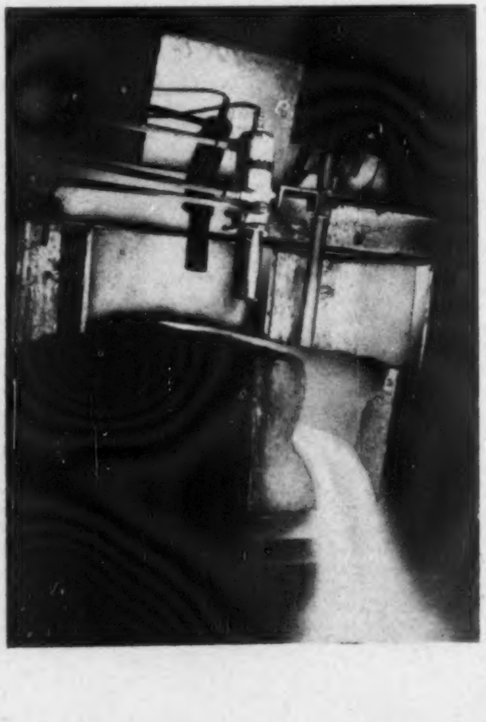
Radiation pyrometer for liquid iron/steel

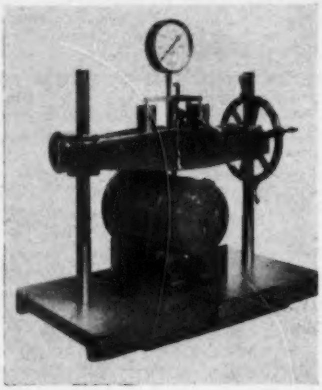
A radiation pyrometer, which meets the foundry industry's growing need for closer control of liquid iron/steel temperatures, has just been introduced by Land Pyrometers Ltd., 318 Queens Road, Sheffield. Known as the R.P. 18, the new pyrometer will measure the temperature of the metal as it leaves the cupola or holding furnace, with an accuracy comparable to that of an immersion pyrometer. (*See illustration below.*)

By using a photocell instead of a thermopile, the manufacturers have successfully eliminated the serious effect of metal emissivity on the accuracy of the reading—the main drawback of previous radiation pyrometers introduced for this purpose. Calibration is for the normal emissivity of a liquid metal stream and the small variations encountered in practice have a negligible effect only on the readings.

The R.P. 18 can be focused on a target as small as 1 sq. in. and is, therefore, easily sighted on the metal stream in the slag box. The pyrometer lens is protected by a window of heat-resisting glass, which can easily be cleaned, or replaced, if accidentally splashed with metal.

To avoid damaging the photocell, a water jacket is supplied with the new instrument in order to keep its temperature below 40°C. The pyrometer is easily clipped into the jacket with an accurately reproducible alignment. Another integral part of the equipment is the air purge unit, which enables an air jet to be blown down the optical path to keep it free from fumes. This also helps to protect the pyrometer window.





Brinell hardness testing machine for large components

Brinell hardness testing machine

Edward G. Herbert Ltd., Atlas Works, Levenshulme, Manchester 19, has recently completed a Brinell hardness-testing machine which has been specially designed for testing large components.

The hand-operated-type Brinell head, similar to those incorporated in the standard machines, comprising of an 8-in.-dia. 0-3,000 kg. pressure gauge, checkweights, hand-operated pump and 10-mm.-dia. ball support assembly, have been fitted into a substantial crosshead. The crosshead is supported on two screws which are located in the heavy cast-iron base and is adjustable to any vertical position by a handwheel.

With a table 44 in. by 24 in. this particular machine has 30-in. clearance between the screws and is adjustable up to a maximum height of 24 in. between the base and the 10-mm.-dia. steel ball. These sizes can be varied to suit individual requirements.

This machine is one of a large range which Edward G. Herbert Ltd. builds under licence from the Tinius Olsen Testing Machine Co., Philadelphia, U.S.A.

Nickel stripper

'Niplex,' a new stripping bath that removes nickel and cadmium without pitting or corroding the base metal, is already widely used in the U.S.A. and Germany. Nickel can be stripped from all metals, including zinc base or copper plate, without impairing the underlying surface. Plating rejects, therefore, do not need to be repolished after stripping.

Niplex solution is non-electrolytic and can be operated cold, or heated up to 80°C. The stripping rate of a fresh bath at room temperature is approximately 0·0025 in./h. of nickel. This can be accelerated by heating the dilute solution up to a maximum of 0·006 in. to 0·009 in./h. The solution contains no cyanide, caustic or acid; it does not fume and is stable for long periods in use or standing. Niplex is so balanced chemically that all the components are exhausted at the same time. In normal use no analytical control is necessary except for replacing evaporation losses with water if the solution is used hot.

Full details of Niplex and technical advice may be obtained from the European Metal Finishing Division of Roto-Finish Ltd., Mark Road, Hemel Hempstead, Herts.

PEOPLE

The Iron and Steel Institute has announced the award of the following medals and prizes:

The Bessemer Gold Medal for 1959 to **Prof. Bo Kalling,** until recently director of research, Stora Kopparbergs Bergslags Aktiebolag, Sweden.

The Sir Robert Hadfield Medal for 1959 to **Mr. Albert Jackson,** technical adviser on steelmaking, the United Steel Companies Ltd.

The Andrew Carnegie Silver Medal for 1958 to **Dr. P. Vasudevan,** Department of Metallurgy, University of Manchester, for a paper on 'The kinetics of bainite formation in a plain carbon steel'; his co-authors, Dr. L. W. Graham and Dr. H. J. Axon, were not eligible for an award.

The Williams Prize for 1958 to **Mr. H. C. Child,** research manager, William Jessops & Sons Ltd., for a paper on 'Vacuum-melting of steels'; his co-author, Mr. G. T. Harris, was not eligible for an award.

Mr. L. Rotherham, M.SC., F.INST.P., F.I.M., Member for Research of the Central Electricity Generating Board, has been co-opted to the Council of the British Welding Research Association.

Mr. Rotherham, who was chief metallurgist and director of research and development, U.K.A.E.A. (Industrial Group), from 1950 to 1958, is a member of the Scientific Advisory Council of the Ministry of Power, and of the General Board of the National Physical Laboratory. He was elected a fellow of University College, London, in 1959.

Mr. Robert D. Hamer has assumed the post of chief executive officer for Aluminium Ltd.'s international sales in Europe, Middle East and North Africa, with headquarters in Zürich.

A graduate of the University of Saskatchewan in chemical engineering and of Charlottenburger Technische Hochschule, Germany, Mr. Hamer has served Aluminium Ltd. in a broad field of responsibility for 23 years. From

Mr. R. D. Hamer

1943 to 1950 he was business manager of Aluminium Laboratories Ltd., closely concerned with the post-war organization of research and development efforts in support of sales.

Since 1950 his activities in these fields have been expanded as vice-president of Laboratories in charge of the Banbury research laboratory and Laboratories' Geneva office.

Mr. Hamer is a Fellow of the Institute of Metallurgists, and the Royal Institute of Chemistry, a vice-president of the Institute of Metals, and a former president of the Aluminium Development Association in Britain.

Mr. E. L. Ashley, manager of the Banbury Works for over a quarter of a century, has been appointed a director of Northern Aluminium Co. Ltd.

Mr. Ashley was manager of the Banbury Works until March 31, 1959, when he accepted a special assignment for the company which will take him, in the first instance, to North America. Joining the organization in 1927

Mr. E. L. Ashley

Mr. Ashley worked in Britain and Canada before moving to Banbury as sheet mill manager in 1931. Two years later he was appointed works manager and in the following 26 years he directed the tremendous expansion of the plant. During the war he was also manager of a shadow factory at Adderbury, a few miles from the main works.

Mr. Arnold Hugo Ingen-Housz, president of the Iron and Steel Institute from 1957 to 1958, has been elected an Honorary Member of the Institute.

Mr. Ingen-Housz, who was born at The Hague, received his technical education at the Technical University of Delft, obtaining a degree in mechanical engineering in 1911. After working with Royal Dutch Shell and the municipality of The Hague, he joined the Royal Netherlands Blast Furnaces and Steelworks Ltd. (Koninklijke Nederlandsche Hoogovens en Staalfabrieken NV) in 1917 as technical assistant to the founder of the company, Mr. Wenckebach, in the planning and construction of the IJmuiden plant.

On the death of the founder in 1924, Mr. Ingen-Housz became joint managing director of the company, together with Mr. Kessler. When Mr. Kessler died in 1945, Mr. Ingen-Housz assumed the position of president of the Management Board (Directie), and held this position until his retirement this year.

When he became president of the Iron and Steel Institute in 1957, Mr. Ingen-Housz was the first overseas member to receive this distinction since the late C. P. E. Schneider, who served from 1918 to 1920.

Mr. L. Bailey has been appointed a director of United Steel Structural Co. Ltd., Scunthorpe, a subsidiary of the United Steel Companies Ltd.

After war service with the Royal Engineers, during

which he became deputy assistant director of transportation to 21 Army Staff Group, with the rank of major, Mr. Bailey joined Appleby-Frodingham Steel Company in 1947 as assistant plant engineer (railways). He transferred to the newly-formed United Steel Structural Company in 1950, becoming assistant sales manager in 1953, production manager in 1955 and was appointed to his present position of works manager in 1957.

Mr. Verdon O. Cutts, manager of the Process Heating Department of the General Electric Co. Ltd. retired recently.

Mr. Cutts, a pioneer in the electro-metallurgical field, started in business in Sheffield in 1909. Apart from his work as a consulting engineer, he specialized in electric furnaces and welding. In 1929 he joined the G.E.C. and built up the Process Heating Department covering electric furnaces, high-frequency heating (both eddy-current and dielectric heating) and infra-red heating. A feature of the Department's activities has been the number of *ad hoc* heating installations which they have undertaken for a wide range of industries.

He has travelled extensively throughout the world and is a Fellow of the Institute of Metallurgists, a member of the Institute of Metals, and other technical Institutes and Societies—to many of which he has contributed papers and lectures. In 1953 he was president of the electric furnace section of the International Congress on Electro-Heat, which was held in Paris.

Mr. Cutts resumes his consulting practice from his home address: 1 Ramsay Lodge, Hillside Road, St. Albans.

Mr. D. A. Senior, M.A., A.M.I.E.E., has been appointed to the newly created post of Scientific Attaché to the British Embassy in Moscow. He will advise the British Ambassador (Sir Patrick Reilly) on scientific matters and report on Soviet scientific and technical development in the civil field.

Mr. Senior, who is 35, will hold the rank of senior principal scientific officer and will be on the staff of the Department of Scientific and Industrial Research.

Mr. Senior joins the D.S.I.R. from the Royal Naval Scientific Service. Since 1950 he has been at the Admiralty Research Laboratory, Teddington, mainly investigating problems of instrumentation and combustion.

Mr. W. E. Nutting, a maintenance fitter employed by Round Oak Steel Works Ltd., Brierley Hill (Staffs.), for over 30 years, is the new president of the British Iron, Steel and Kindred Trades Association and is the first Midlander to hold that office. He is a member of the executive council of the Iron and Steel Trades Confederation.

Mr. Allan Ray Putnam has been appointed managing director of the American Society for Metals. As managing director of the Metal Society, Mr. Putnam will occupy a new position established by the ASM Board of Trustees following the death last year of William H. Eisenman, a founder-member of the Society and national secretary and executive head for 40 years.

Mr. Putnam comes to the American Society for Metals from Detroit, where he is assistant executive secretary of the American Society of Tool Engineers. He will assume his new ASM position in Cleveland as soon as his present commitments are concluded.

Sir Ewart Smith, F.R.S., has just retired from the board of Imperial Chemical Industries Ltd.

An engineer of distinction—he obtained 1st Class Honours in the Mechanical Science Tripos at Sidney Sussex College, Cambridge—Sir Ewart joined Synthetic Ammonia & Nitrates Ltd. (later the Billingham Division of I.C.I.) in 1923, and subsequently played a part in the major development of the huge Billingham complex, becoming its chief engineer in 1932. He was seconded to the Ministry of Supply in 1942 to be chief engineer and superintendent of Armament Design. He returned to I.C.I. in 1945, when he was appointed technical director, and was knighted for his wartime services in 1946. In 1955 he was appointed deputy chairman.

Sir Ewart does not intend to retire from active life. The Parliamentary Secretary to the Ministry of Health recently announced that Sir Ewart had agreed to serve as chairman of a new council which has been set up to assist the application of modern industrial techniques in the National Health Service.

Ald. A. V. Wolstenholme, who is on the staff of Thos. Firth & John Brown Ltd., Sheffield steelmakers and engineers, is to be Sheffield's next Lord Mayor. He was born in Sheffield and has been a member of the City Council for 20 years.

OBITUARY

The sudden death occurred in Chesterfield Royal Infirmary last month of **Mr. Ian Heathcote,** technical sales representative of Brayshaw Furnaces Ltd., Manchester.

Mr. Heathcote joined the outside sales staff of Brayshaws in 1955, and was well known in engineering circles in Sheffield, Rotherham and North East England.

INSTITUTE OF METALS

THE FOLLOWING MEMBERS have been elected to fill vacancies on the Council of the Institute of Metals:

President: G. L. BAILEY, C.B.E., M.SC., F.I.M. (director, The British Non-Ferrous Metals Research Association).

Past President: Marshal of the Royal Air Force, THE LORD TEDDER, G.C.B., D.C.L., LL.D., D.LITT., HON. M.I.C.E. (Chancellor, University of Cambridge; chairman, Standard Motor Company Ltd.).

Vice-Presidents: HUGH FORD, D.SC., PH.D., WH.SCH., M.I.MECH.E. (Prof. of Applied Mechanics, Imperial College of Science and Technology, University of London); E. H. JONES, A.R.I.C., M.I.M.M. (joint managing director, Capper Pass & Son Ltd., North Ferriby), and H. O'NEILL, M.MET., D.SC., F.I.M. (Prof. of Metallurgy, University College of Swansea, University of Wales).

Honorary Treasurer: D. P. C. NEAVE, M.A., M.I.MECH.E. (director, the British-American Metals Co. Ltd.; Capper Pass & Son Ltd.; James Bridge Copper Works Ltd.; and Wolverhampton Metal Co. Ltd.).

Ordinary Members of Council: W. O. ALEXANDER, B.SC., PH.D., F.I.M. (assistant research manager, Imperial Chemical Industries Ltd., Metals Division, Birmingham); N. P. ALLEN, M.MET., D.SC., F.I.M., F.R.S. (Superintendent, Metallurgy Division, National Physical Laboratory, Teddington); F. DICKINSON, B.SC.(ENG.), F.INST.P., F.I.M. (manager, Development and Research Department, the Mond Nickel Co. Ltd., London); and L. ROTHERHAM, M.SC., F.INST.P., F.I.M. (Research Member of the Central Electricity Generating Board, London).

BOOKS

Calibration of liquid-in-glass thermometers

By J. F. Swindells, National Bureau of Standards Circular 600, issued January, 1959, 21 pages, 20 cents (25 cents post free). Available from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

THIS CIRCULAR gives information needed for the efficient use of liquid-in-glass thermometers. It describes, for manufacturers of such thermometers, the features of good design that will permit the instruments to realize the full accuracy of which they are capable. Methods of calibrating thermometers, also described, will interest those who calibrate their own instruments as well as those who submit them to the National Bureau of Standards for calibration.

The liquid-in-glass thermometer is probably the most widely used device for measuring temperature, but it is not entirely foolproof. However, if used with awareness of its inherent limitations, and if properly constructed, it can give excellent service where reliable measurements are desired.

The circular discusses such topics as materials of construction and scale design. Consideration is then given to various factors that affect the use of the more common types of thermometers: total-immersion, partial-immersion, low-temperature, Beckmann, calorimetric, and clinical. Details are presented on the calculation of emergent stem corrections; and there are discussions of sources of error such as thermometer lag, gradual changes in the glass, and changes in bulb volume due to annealing. The techniques and equipment used in the N.B.S. calibration procedures are described and information provided on the eligibility requirements and application for the Bureau's calibration services.

Non-destructive testing

By J. F. Hinsley. Macdonald & Evans Ltd. London, 1959. £3 16*s*. 9*d*. net.

THE TOPICAL IMPORTANCE of the subject of this book has been made evident by the recent Symposium organized by the Institute of Physics. The sleuths are providing us with apparatus giving evidence of curious features in metals which might be frightening if not interpreted in a sensible manner. The honest manufacturer wants to supply a satisfactory product and therefore welcomes tests which help him to this end, but armed with them, the inexperienced inspector might be responsible for a lot of unnecessary scrapping. The author of this book is in a good position to give a balanced story, since he was in the Aeronautical Inspection Department for seven years and is now chief radiologist and physicist to a firm which specializes in making steel castings. He has produced an excellent account of the subject.

Non-destructive testing has reached such a pitch when applied to the high-duty steel rotors of large electrical generators that extreme precautions have to be taken in their manufacture if much scrapping is to be avoided. In this connection the index of the book enables us to turn up information about the ultrasonic detection of hair-line cracks, but it misses an account of their magnetic detection given on p. 36 and again on p. 262. Nevertheless, it is a very full index and castings are dealt with on pp. 30—36 and elsewhere. The wide range of procedures described may be gathered from the inclusion of several pages on acid pickling tests on steel castings.

Perhaps the most fascinating sections deal with the development of ultrasonics. There is mention on p. 225 of the regular checking of the axles of railway rolling stock for transverse fatigue cracks. Unfortunately, fig. 11.7 illustrating this is unusual, for generally the wheel seat of a vehicle comes *between* the journal and the body of the axle and the cracks that cause the trouble are *inside* the press fit and not outside as shown. The same page deals with testing large cast rolls, and it would be interesting to know if any conclusions have yet been reached regarding non-destructive examination for the depth of the hard zone in chilled iron rolls and hardened steel rolls.

The sections on radiology and on magnetic testing methods are very expert. There was a time when internal stresses in steel appeared to produce displays during magnetic testing, but this does not appear to be dealt with in the work. Chapter 17 on X-ray and other diffraction techniques gives brief indications of the information obtainable by these methods. There is also a chapter on the mathematics of non-destructive testing which is intended to simplify things for operators, especially in interpreting radiographs and evaluating flaw depths.

One can say that this admirably illustrated work of 477 pages on a vital subject by an experienced specialist is good value for money.

HUGH O'NEILL

Cast tools

By Z. Eminger and V. Koselev. Translated from the Czech edition by Ch. Caslavsky and G. A. Evans. Constable & Co. Ltd. London, 1957. 8 x 6 in. Pp. 230 + 177 illustrations. 20*s*. net.

THIS REMARKABLE LITTLE BOOK describes the experimental background which has culminated in the successful commercial production of cast high-speed tools of the usual sizes required by engineering machine shops. The book is eminently worthy of study by everyone interested in precision casting using either transient wax patterns or permanent metal patterns. The various methods of casting into the final mould are all considered, but by far the greatest attention is given to the simpler inverted furnace casting technique.

The production of tools (hot cutters, milling cutters, end and face milling cutters, reamers and drills) varying in weight from 0·5 kg. up to 40 kg. are all described and the various stages of manufacture fully illustrated by a large number of photographs and line drawings. The possibility of extending the application of the inverted furnace casting method to the production of larger tools and machine parts (die blocks for steel pressings, geared pinions, etc.) is also considered. On the other hand, it is stated that the production of very small tools weighing only several dekagrams (small twist drills, milling cutters, etc.) is not practicable due to insufficient toughness in the small castings.

It is claimed that the cast tools can be considered as equivalent substitutes for the more expensive traditional tools made from forged blanks. Although cast tools are more brittle, and require greater care during processing and in operation, it is claimed that their lower toughness is more than adequate for normal service conditions. Furthermore, it is also claimed that this reduction in toughness actually confers a beneficial effect upon the cutting properties of the tool. While comparative data on tool life for forged and cast tools are given to substantiate these claims, it is felt that the true place of the cast tool

Electrical Aids in Industry — *Data Sheet* **No. 5**

Resistance Heating – 2

Electric resistance heating elements have been briefly described in Data Sheet No. 4, with two examples (in furnaces and ovens) of their application in industry. This sheet lists some of the further applications which can be effectively dealt with by resistance heating.

Soft Metal Melting

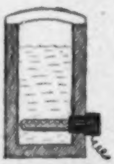
Electric resistance melting is most commonly used for lead, tin, zinc, antimony, aluminium and their alloys – in processes such as tinning, type-casting, die-casting and lining bearings — at temperatures of up to around 800°C.

In most cases, sheathed lements are immersed directly in the metal, a more efficient method than applying heat to the outside of the containing vessel or pot. Immersion heating simplifies the application of lagging to the outside of the vessel, reducing heat losses and current consumption to a minimum.

In all cases, the precise temperature control that is so essential in soft metal processes is readily achieved by the use of electricity, and electric heating also leads to a reduction of casting rejects and metal wastage and a marked improvement in working conditions.

Liquid Heating

Electricity provides an excellent way of heating liquids such as water, oils and varnishes; plating, photographic and other solutions, and of melting and heating waxes and compounds, glues and pastes, tars and bitumen. Again, immersion heating is the method most commonly employed.

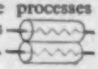


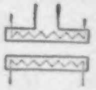
Fire hazards associated with inflammable liquids are invariably reduced by electric heating, particularly if immersion heaters are used.

It is usually possible without difficulty to apply electric heaters, either immersion or external, to existing vessels.

Platen, Press and Roll Heating

Electricity offers the simplest and most convenient method of heating platens, dies and rolls. It gives the precise temperature-control characteristic of electric heating systems, with lower maintenance costs. Moreover, the relatively high temperatures required in some processes for maximum working speeds are reached without difficulty.

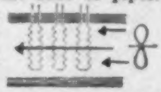




When electric heating is used, one or more presses can be operated without the necessity of keeping a boilerhouse staff at work.

Air Heating

Streams of air, and of many other gases, can be heated most efficiently by electric resistance elements. Heat is generated only inside the duct, and none is carried away through exhaust flues or pipes. Quick rise of temperature and precise temperature control are thus assured.



Electric Steam Boilers and Steam Raising

There are many cases when the use of electricity for steam raising is fully justified on economic grounds.

The means employed for bringing steam from a boilerhouse to the point of usage are often extremely wasteful. The efficiency of the electric boiler normally exceeds 96% and is practically constant at all loads.

Plant requiring process steam can be equipped with its own electric steam boiler, freeing the working space of steam mains just as individual electric motor drives free the factory of masses of shafting and belt drives.

Even where boilerhouse steam is still used, it is sometimes desirable for best results to boost the steam temperature at the point of usage, to make up for transmission heat losses or to increase the superheat, and this function is most conveniently performed by an electric resistance heater inserted in the steam line.

For further information get in touch with your Electricity Board or write direct to the:
Electrical Development Association, 2 Savoy Hill, W.C.2. Tel: TEM 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available – "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

CUT HERE

in the machine shop will need more supporting evidence than that given here.

Additional chapters on the metallurgy of melting and casting, heat treatment and the metallography of high-speed steel are also included. A short bibliography covering a selection of references up to 1953 completes the contents.

The translation abounds with numerous spelling mistakes and grammatical errors but these are of little consequence to a full appreciation of the subject matter.

H. K. L.

Using steel wisely

By L. Aitchison and W. I. Pumphrey. Macdonald & Evans Ltd. London, 1958. Pp. xxii + 241. Illustrated. £2 4s. net.

As MAY BE DEDUCED from the title, this book is primarily concerned with a review of the principles underlying the selection of the correct steel for engineering applications. The actual metallurgical content of the book could readily be dismissed as elementary, but the way in which the authors present this information and discuss its implications on the mechanical performance of steel makes for most interesting reading. The overall result cannot fail to give the reader a much clearer understanding of the characteristic properties of steel and, as such, the book should find more appeal amongst engineers rather than metallurgists.

Starting from the premise that no piece of industrial steel is either homogeneous or isotropic (design engineers beware!) the authors briefly discuss the sources of the various operative imperfections found in steel. These vital features are later given further prominence when discussing such topics as factors of safety (or ignorance) and the various terms generally classified under the omnibus title of 'mechanical properties.' In particular, the concepts of ductility and toughness are deservedly singled out here for special treatment.

The book is divided into two distinct sections. Part I, 'Creating a component,' is concerned with a short treatment of the problems associated with casting an ingot, fabricating the wrought section by hot and cold working, heat treatment, surface treatments and quality control. Both plain carbon and alloy steels are considered, but for obvious reasons of space, no real attention is paid to austenitic steels. The fabrication and characteristics of shaped steel castings are also omitted. Part II, 'Making the best of it,' considers the implications of the characteristics acquired by wrought steels during fabrication and thermal treatment and carefully analyses the best ways of selecting and using a steel to its best advantage.

H. K. L.

International Tin Research Council, Annual Report, 1958

Tin Research Institute, Fraser Road, Greenford, Middlesex.

THE annual report on the work of the Tin Research Institute mentions many newly discovered facts about tin, its alloys, and chemical compounds.

Metal industries will find many items of interest, including the work on new alloys of tin with 'newer' metals such as titanium. Tin-nickel plating is now being taken up by watch and instrument industries for which this plating has much to commend it.

The Institute continued its free technical advice services to firms and individuals all over the world and sent out 125,000 copies of its publications.

Libraries and translations

Chinese scientific literature

THE LENDING LIBRARY UNIT of D.S.I.R. has started to collect Chinese scientific literature. About 150 Chinese periodicals are now on regular order and the first batch has arrived at the Library's London premises.

Already the Lending Library Unit is noted for its large collection of Russian scientific literature, which is available to research, industrial and other organizations, through a loans service. The Library also organizes a scheme for the translation of Russian scientific literature, in collaboration with the National Science Foundation in the United States. This may possibly be extended in the future to include scientific literature from China. Meanwhile, the contents of these Chinese publications must be assessed, and a scientist with a knowledge of Chinese is being recruited by L.L.U. to select and promote use of Chinese scientific and technological literature.

The Lending Library Unit in London is the nucleus of the new National Lending Library for Science and Technology, which will be set up at Thorp Arch, near Boston Spa, Yorks., in 1961.

Russian translations

Starting with the January, 1959, issue, the Chemical Society is to publish, with the support of the Department of Scientific and Industrial Research, a cover-to-cover translation of the monthly journal, *Zhurnal neorganicheskoi Khimii*, a publication of the Academy of Sciences of the U.S.S.R. The translation will be undertaken for the Society by Infosearch Ltd., and the Society has appointed Professor P. L. Robinson as Executive Editor of the publication. Professor Robinson will be assisted by an advisory panel of distinguished inorganic chemists.

The sale and distribution of the journal will be undertaken by Cleaver-Hume Press Ltd., 31 Wright's Lane, London, W.8, from whom a detailed prospectus giving the scope of this journal may be obtained.

Translations will be issued in monthly parts as soon as possible after the Russian original is available. The subscription rate will be £30 (U.S.A. $90) per annum, but Universities and technical colleges may subscribe at a discount of 25%. Single issues can be purchased at £4 (U.S.A. $12) per copy to all purchasers.

The Society also hopes to start the publication within the next year of translations of the Russian 'Journal of Physical Chemistry' (*Zhurnal fizicheskoi Khimii*) and 'Progress in Chemistry' (*Uspekhi Khimii*).

By arrangement with the Department of Scientific and Industrial Research, the Iron and Steel Institute is undertaking the monthly publication of a complete English-language version of *STAL* (*Steel*) starting with the issue of January, 1959. *STAL* is the major Russian periodical in the sphere of iron and steelmaking technology, in which many of the more significant developments are reported. It is hoped in this way to make this work much more widely known.

The subscription rate is £20 per year (12 monthly issues), but for Iron and Steel Institute members is £15. Single copies are £1 10s. for members and £2 for others. Universities and technical colleges may subscribe at a discount of 16⅔%.

COMPANY NEWS

Northern Aluminium Company Ltd. will shortly establish a new branch of its aluminium fabricating industry in New Zealand. This decision is the outcome of discussions held between the company and the New Zealand Government over several months.

The new plant will have an initial production capacity of 5,000 tons per annum of aluminium sheet and foil products and 2,000 tons per annum of aluminium wire and cable for electrical transmission lines. The location of the plant has yet to be decided.

The general manager of the New Zealand branch will be Mr. T. E. L. Ashley, who has spent over 30 years in the aluminium industry in England and has been manager at Banbury for the past 25 years.

The address of the new **Firth Cleveland Group** Canadian office is Firth Cleveland Ltd. (Canadian Office), 94 Laird Drive, Toronto, 17, Canada (Hudson 3-2775).

Mr. E. W. Nicholls, of the Firth Company Ltd., has been appointed manager of the Group's Canadian Office, and has left for Canada to organize the new office.

Short & Mason Ltd. is opening a branch office at 30a London Road, Manchester, 1 (Central 3044). Mr. William K. Gregson has joined Short & Mason as the northern area representative.

The Electric Motor Division of **Newman Industries Ltd.** has opened an additional area office at 59 Grey Street, Newcastle upon Tyne, 1 (Newcastle 2-3970). The new area manager is Mr. R. Martindale.

A new sub-office of the **English Electric Company** has been opened at 14 Albert Road, Middlesbrough (Middlesbrough 44346/7). Mr. A. R. Johnson, B.SC., A.M.I.MECH.E., A.M.I.E.E., A.M.I.PROD.E., is in charge and is responsible to the manager of the 'English Electric' branch office at Newcastle upon Tyne, Mr. W. D. M. Lywood, A.M.I.E.E.

Delapena & Son Ltd., manufacturer of induction heating and honing equipment, has now moved the major part of its administrative staff to new offices in Cheltenham. The address is Tewkesbury Road, Cheltenham, Glos. (Cheltenham 56341) (Telex 43354).

The **Incandescent Heat Co. Ltd.** has for some years manufactured process equipment to the designs of the Swenson Evaporator Co. (a division of the Whiting Corporation) of Harvey, Illinois. An agreement has now been reached by which Incandescent has exclusive selling and manufacturing rights in the United Kingdom for all Swenson products.

To handle this work a Chemical Plant Division has been formed, headed by Mr. C. J. V. Denning.

Classified Advertisements

SITUATIONS VACANT

A WELL-KNOWN COMPANY in Birmingham have a vacancy for a Manager to assume responsibility of running a plant to produce cold flow forgings. The position offers excellent prospects to a first-class man possessing real practical knowledge, managerial ability and drive. Salary will be in accordance with qualifications and experience. Applicants must give full particulars of age, training, experience and salary expected.—Box AW 116, METAL TREATMENT AND DROP FORGING.

BIRLEC HEATING DIVISION SALES DEPARTMENT WANT FURNACE DESIGN ENGINEER. Duties include discussions with customer and liaison with Engineering Department designers and estimators, and preparation of project and tender specifications. H.N.C. or Engineering Degree standard. Apply to Personnel Manager (JMP), Birlec Ltd., Tyburn Road, Birmingham 24.

PROGRESSIVE DROP-FORGING COMPANY, interested in development of modern metal flow techniques, invites applications for a staff appointment to take charge of Laboratory and Inspection Departments.—A. J. Vaughan & Co. (Mitre Works) Ltd., Mitre Works, Wolverhampton Road, Willenhall, Staffordshire.

AGENCY

AGENCY REQUIRED for drop forgings in London and Home Counties. Good connection for best-quality forgings only.—Box AR 115, METAL TREATMENT AND DROP FORGING.

FOR SALE

CALCIUM SILICIDE. Finely ground calcium silicide—for nodular iron, exothermic compositions, etc. (now being successfully used by several foundries) *at prices which save you money*. Toxane Ltd., 47 High Street, Edgware, Middlesex. EDGware 6666.

SIX UNUSED BLISS 60-ton double-geared twin-drive spur-geared downstroking mechanical presses. Fitted two electric motors, one 40-h.p. slip ring Metrovick, 1,000 r.p.m. on hinged plate. Vee-belt drive. Other motor for reversing adjustment 7½ h.p., 750 r.p.m. Hand-operated friction clutch. Crankshaft pin 4½ in. diameter, 35 to 1 ratio. Length of stroke 45 in. Adjustment of punch stem inside 19 in. approx. Slide counterbalance by weight in gears. Type 14T. Overall weight approx. 20 tons. Hodson & Co. (Machinery) Ltd., Spring Mills, Tottington, near Bury, Lancs. Tel. TOTT 123/4.

HYDROGEN COMPRESSOR by Bellis & Morcom. Weight 2 tons. Wild-Barfield forced-air circulatory furnace. Max. temp. 750°C. Fitted with variable pattern excess temperature cut-out. Oil-cooled mains transformer, contactor panel, charge progress recorder and time switch. As new.

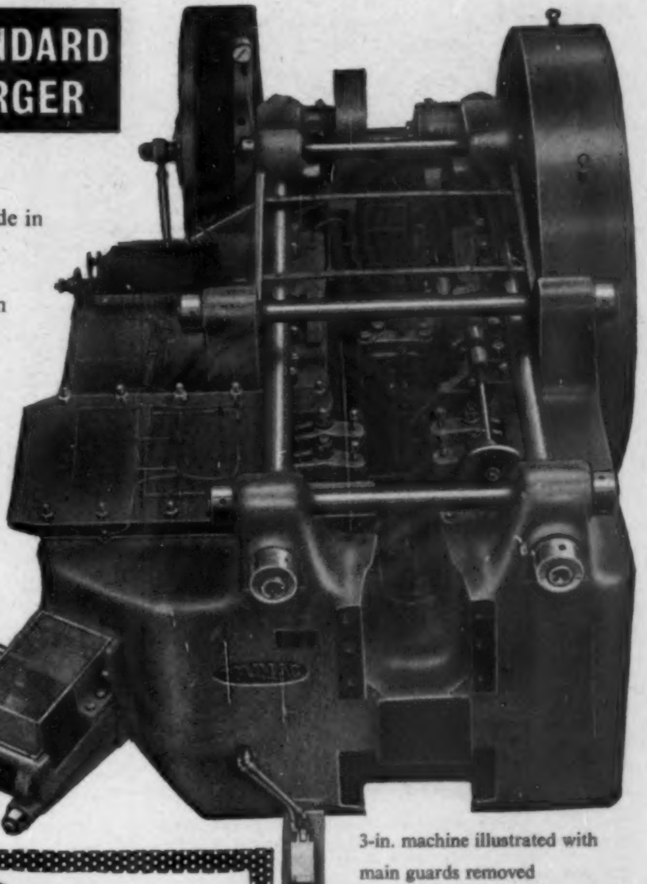
Gas-fired furnace by Lucas, 72 in. × 42 in. × 22 in., 1,100°C., complete less floor. Furnace, gas fired, by Lucas, 33 in. × 24 in. × 12 in., 1,200°C., in poor condition.

Salt bath by Lucas, 6 ft. × 4 ft. 9 in. × 3 ft. 6 in.

Ditto by Haslam.

Ammonia cracker by I.C.I. for manufacturing cracker gas for heat treatment and welding applications, etc. Colbro Ltd., Wood Lane, Rothwell, Leeds. Phone: Rothwell 3258.

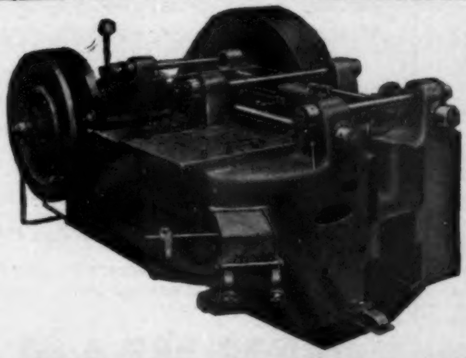
COVMAC STANDARD FORGER



Covmac Forging Machines are made in eight sizes to take bars from 1 to 6 ins. in diameter. Safety devices on all models prevent overloading.

Covmac also make Automatic Forging Machines, as well as machines for making balls up to and including 4 ins. diameter. In addition there are three sizes of Hot Milling and Sawing Machines.

3-in. machine illustrated with main guards removed



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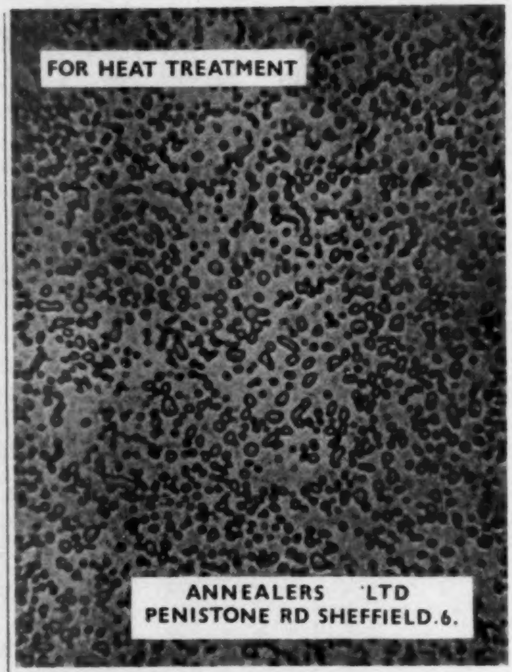
OVERSEAS AGENTS: AUSTRALIA: Gilbert Lodge & Co. Ltd., 386 Harris Street, Ultimo, Sydney, N.S.W. CANADA: Williams & Wilson Ltd., 544 Inspector Street, Montreal. FRANCE: Societe Anonyme Alfred Herbert, 1 & 3 Rue du Delta, Paris (9e). HOLLAND: Esmeijer & Co., Oosterkade 24, Rotterdam, C. INDIA: Alfred Herbert (India) Ltd., 13/3 Strand Road, P.O.B. 681, Calcutta, 1. NEW ZEALAND: Gilbert Lodge & Co. Ltd. Head Office: 24 Gt. South Road, Newmarket, Auckland, N.Z. (P.O.B. 9194, Newmarket); also at Christchurch and Wellington. PAKISTAN: Guest, Keen & Nettlefolds in Pakistan Ltd., P.O.B. 819, Bank of India Buildings (3rd Floor), Bunder Road, Karachi. SOUTH AFRICA AND RHODESIA: Hubert Davies & Co. Ltd., Hudaco House, 7 Rissik Street, Johannesburg. SPAIN: Gumuzio S.A. Gran Via 48, Apartado 920, Bilbao.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